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IRON AND STEEL ENGINEER

JUNE • 1939

VOL. XVI NO. VI

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Published Monthly by

ASSOCIATION OF IRON AND STEEL ENGINEERS

Entered as second-class matter January 25th, 1924, at Pittsburgh, Pa., under the Act of March 3rd, 1879.

Statements and opinions given in articles and papers appearing in "Iron and Steel Engineer" are the expressions of contributors, for which the Association of Iron and Steel Engineers assumes no responsibility.

Single Copy Foreign Prepaid $2.00 Single Copy $1.50
Subscription price in U. S. & Canada .....$ 7.50 per year
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Protection of BRANCH CIRCUITS for Auxiliary MOTORS

By WILLIAM DEANS

I. T. E. CIRCUIT BREAKER COMPANY

PHILADELPHIA, PA.

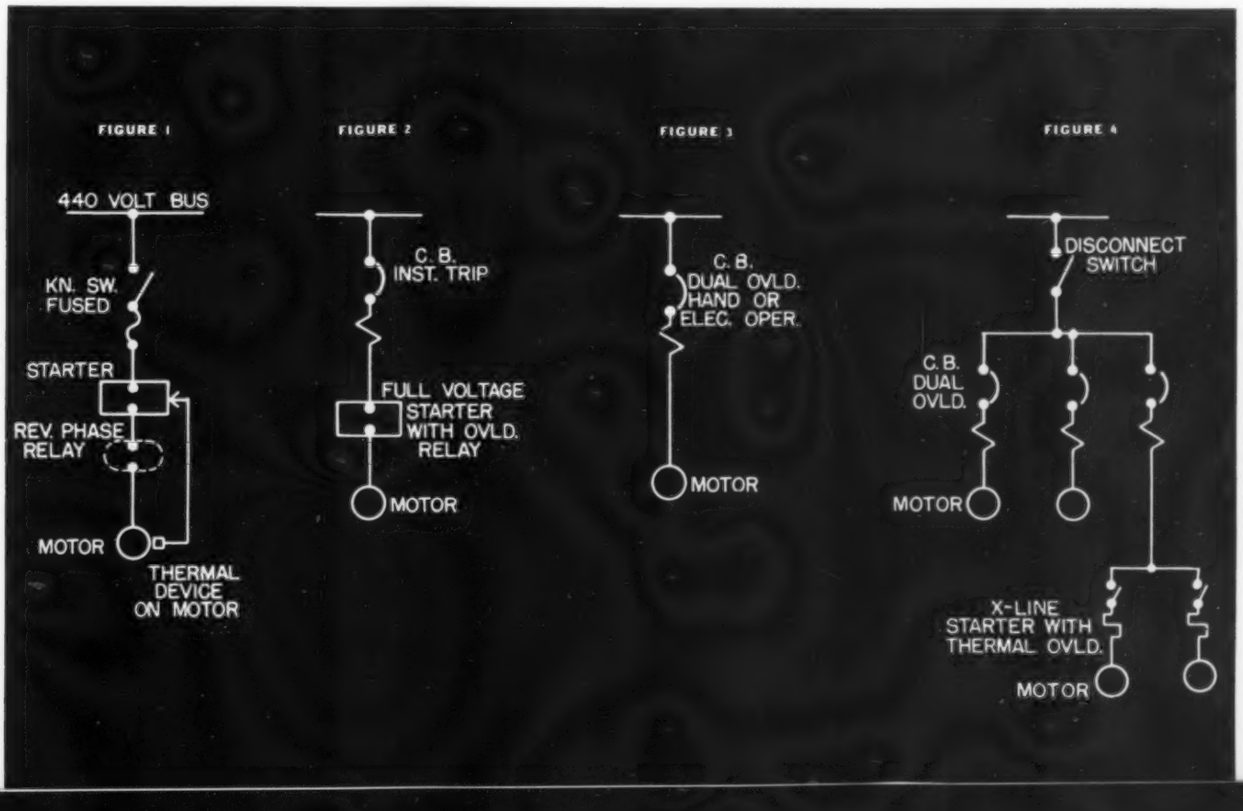
▲ PROTECTION applied to a motor circuit in general involves consideration of the protection of the motor itself and the protection of the circuit as such. In many industrial applications a device which protects the motor may be adequate for the protection of the circuit, and the two phases of the problem may therefore be combined, and treated as one. In steel mills, however, the total capacity of the sources of power feeding the circuit of the auxiliaries is so high that each phase of the problem must be individually considered. The motor requires attention from its own point of view, and since when a fault occurs, the motor vanishes as a means for limiting the magnitude of the fault current, the protection of the circuit involves factors independent of the motor but bearing directly to the characteristics of the circuit itself. The two phases of the problem are therefore quite independent of each other.

In the protection of the motor, the controller plays its part so some attention is devoted to the sorts of motor controllers in common use.

For the protection of the motor against overcurrent certain forms of overload relays, operating in conjunction with the controller are used. All of these relays

FIGURES 1, 2, and 3 (below)—Illustrate diagrammatically single motor circuits, each taken from the bus which is protected by a circuit breaker. The overload relay is sometimes omitted from the motor starter, thus relying wholly on the thermal device on the motor.

FIGURE 4 (below)—Shows circuits where the breakers are grouped behind a disconnect switch. The breaker then serves either as a starter or as a protector for a group of motors each having its own starter.



are not adaptable for use with interrupters for the protection of the circuit; some are.

To arrange adequately for the protection of the circuit a complete analysis of the circuit is necessary. Such a complete analysis involves us in electrical and in other points of view.

Alternating current is almost universally used for driving auxiliaries. Direct current is used where speed control of individual units is required. Where speed control of whole groups of motors is necessary, such as on runout tables, that group is fed from an adjustable frequency motor-generator set. The motor of that set is d-c., and of course adjustable speed.

Direct current is 250 volts for auxiliaries. The voltage used on strip mill main drives is 600 volts d-c. This paper has to do with auxiliaries; but the strip mill main drive circuit is mentioned because circuits fed from that main circuit must receive special attention, for protection against conditions of short circuit.

Alternating current circuits are, I think, without exception 3-phase. A number of plants use 25 cycles but the tendency is toward 60 cycles. Mills are no longer generating all their power but are buying power from outside or using outside power as a standby source, and outside power is 60 cycles. The voltage is 440 volts in nearly all cases, for the lower horse-power auxiliaries. For the larger power requirements, 2200 volts is used, as for instance on large pumps. The line is not clearly drawn between the two voltages but below 150 to 200 hp., 440 volts is used and above that, 2200 volts.

Motors are of the usual sort, generally speaking, for both d-c. and a-c. The a-c. motors are induction (squirrel cage) type in the smaller sizes and for the larger sizes, squirrel cage and synchronous motors are used depending upon particular conditions.

The size of transformer banks for the circuits of auxiliaries varies among the plants. In some cases as low as 900 kva. banks are used, in others as high as 3000. Several installations use 3000 and 2400 kva. banks. And in some cases, the secondary circuits are interconnected, so that transformer banks feed in, in multiple, to the 440 volt system.

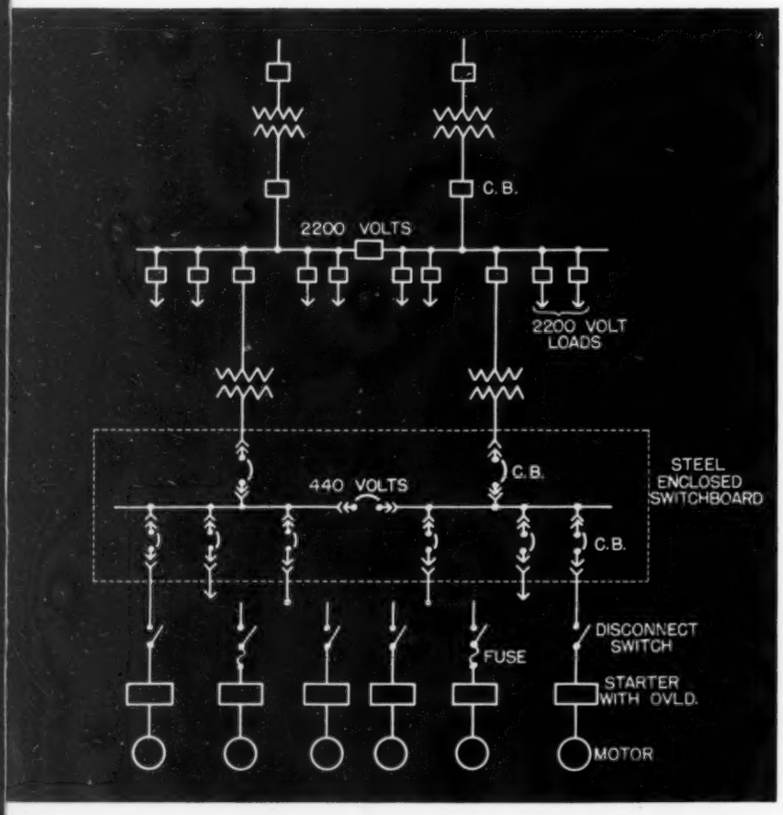
There is no uniformity as to the nature of the secondary system. It varies from a pure radial system to a combination of radial system and network. Upwards of 20000 kva. of transformers feed into some interconnected secondary systems of the combined ring bus and radial type. The whole system exists in an area whose greatest dimension is less than half a mile. It is apparent, then, that a good short circuit on such a system, can cause currents of considerable magnitude. The problem of protection on such a system is not an easy one; it demands very careful attention.

Even in the cases of transformer banks operating singly, the magnitude of the fault currents should receive attention. At a distance from the transformer corresponding to about 10 per cent reactance, a 3000 kva. bank will give about 40000 amp., a 2400 bank 32000 amps., a 1200 bank 16000 amp., and a 900 kva. bank 12000 amp., on a dead (3-phase) short. Such are the magnitudes of the currents to be interrupted in case of a short. And the device called upon to handle those currents must be equal to its job.

Where the secondaries are interconnected either simply or in more complex fashion, the short circuit currents may be many times the values just given. No rule of thumb gives the answer in such cases; the system must be analyzed by pencil and paper, or by the use of the calculating board, to determine the requirements of the interrupting devices.

The starters for the motors of auxiliaries are of all sorts. There is the plain hand starter where the operator moves a handle, and by his energy, the circuit to the motor is suitably adjusted. There is the magnetic starter; it responds to some pilot device. The pilot device may be automatically operated, sensitive to some varying condition such as pressure or level of liquid or something else. Or it may be manually operated as in the case of a push button or master switch. The pilot device being operated to start the motor "tells" the magnetic starter, and the latter goes through the required sequence, automatically, finally getting the motor on the line, under proper conditions of speed, etc. Then the operator (either a person or some robot) "tells" the controller to stop (or perhaps change the speed of) the motor, and its command is obeyed. For magnetic starters, there is a definite preference for definite time acceleration, except in some cases of synchronous motors where slip frequency is used. And even there there is an overall timing device, which will disconnect the motor at the end of a measured interval, unless meanwhile, the accelerating operation has been satisfactorily completed.

FIGURE 5—Typical installation diagram of steel-enclosed, factory-built switchgear, with breakers of the withdrawal type.



For d-c. motors, the controllers are usually for the adjustment of speed, and of course use resistors properly connected in armature and field circuits. The variable voltage system is not usually used for auxiliaries as it is for the main drives. The reason is obvious; a variable voltage scheme requires a generator and the controlled motor to be a pair—a pair of machines devoted to that specific task. It is more economical, considering the sizes of the units to use d-c. at constant voltage, and control the speed by the usual means. One exception to this is the case of run-out table motors driven by d-c. There the whole group of motors may be simultaneously controlled by an adjustable voltage supplied from a motor-generator set.

For the a-c. motors, whether squirrel cage or synchronous the starter is of the full voltage, or across-the-line type for all small motors, primary resistor type for the next larger sizes, and either series reactor or auto-transformer type for the largest motors. In the last case, there is a definite preference for the series reactor type of starter. Experience, and purposely-made tests indicate less line disturbance for the series reactor type. An auto-transformer type starter reduces the starting current during the first part of the starting sequence but when the motor is switched from the starting voltage to full line voltage, there is frequently a very high current peak—high enough to be troublesome from a voltage regulation point of view in a few cases and to trip out instantaneous overload relays in most cases. The reactor element of the series reactor starter may be made exceptionally rugged. For the larger synchronous motors this device is often of the air core type, similar to the air core reactors used for current limiting. These reactors are usually provided with several taps so that the starting conditions may be adjusted, with some precision, consistent with the load requirements.

Overload devices, sometimes but not always associated with the motor controller, are essentially relays, and may be classified in two general groups:

a. Those responsive to current in the motor circuit, and

b. Those responsive to the thermal conditions of the motor itself.

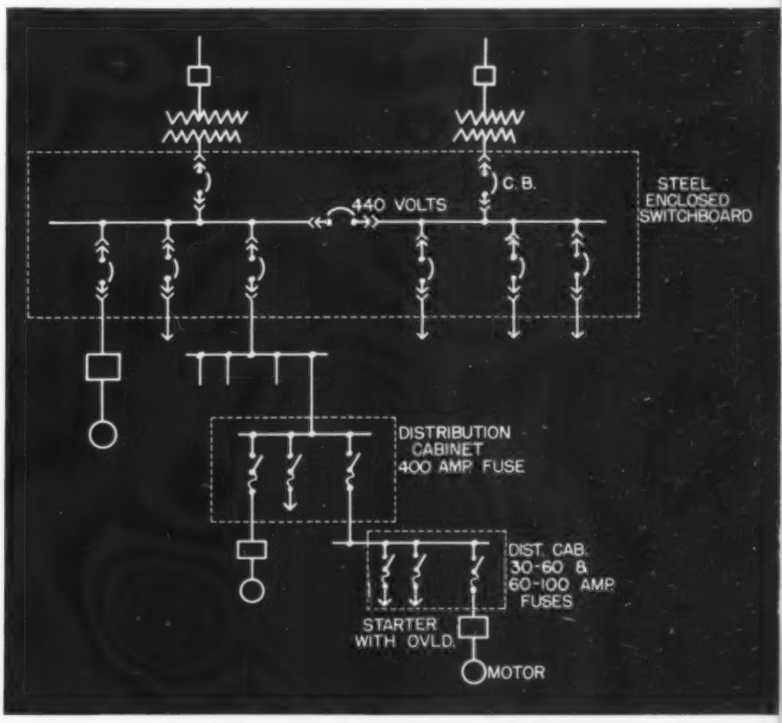
The device is a relay because it, in itself, does not open the motor circuit; it is connected to the switching device which does, either electrically or mechanically. The starter, or controller, with which this device is to be used, must therefore be adapted for suitably responding to its action. If the relay operates by an electrical interlock, the starter must have a no voltage release (or protection) feature or a shunt trip device. If the interlock is mechanical, the overload relay must trip a latch or the equivalent.

There are, too, other overcurrent devices such as thermal cut outs which open the main motor circuit directly. Fuses, especially those of time lag characteristics, might also come under this classification, although fuses generally have much higher interrupting ability than thermal cut outs. Thermal cut outs are applied only to relatively small motors. On overcurrent, a a definite part of the thermal cut out is destroyed, and it must be replaced to re-establish motor operation.

The overload relay devices responsive to current may, themselves, be classified as to whether they are instantaneous, time delay, or a combination of both. All, however, operate according to the current flowing through them, (sometimes their action is modified by other conditions, such as ambient temperature). Their effectiveness, in protecting the motor windings against injury, depends upon the accuracy of the conclusions as to the effect on the motor windings, of the combination of current and time for which the relay is set.

The type of overload relay responsive to temperature of the motor would seem, at first thought, to be the most direct and most reliable means for protection. It is a device which does something about it when the temperature of the motor reaches a certain value. But let us not arrive at a definite conclusion on a poor premise. This device is responsive to its own temperature; that is all it can do. Its temperature is closely that of its surroundings; but are those surroundings at the temperature of the part of the motor to be protected? It is almost never of any importance how hot the frame of a motor gets. It is important, though, that the temperature of the windings does not reach a value dangerous to the insulation, or the copper itself. The heat is generated in the windings on an overload. It takes time for that heat to be transmitted elsewhere. Moreover, there must be a temperature drop to transmit the heat. The windings are therefore hotter than the outside of the frame, for instance, and there is a time delay in the transmission of the heat to the outer surfaces. It is evident, therefore, that unless the location of the temperature responsive device be correctly chosen, an overload may be of sufficient magnitude, and exist for such an interval, as to cause damaging temperatures in the windings before the temperature at the location of

FIGURE 6—Typical circuits using steel-enclosed switchboard, showing the scheme of distribution to small loads.



the protective device has risen to that value at which it will tell the controller to take the motor off the line. The success, or failure, of the device by itself in protecting the motor depends upon its location in (not on) the motor and the temperature at which it is set to function. However, supplemented by other devices such as those discussed later, it is possible to obtain rather complete protection, with less refinement as to the location of the device than has just been indicated.

Those overload relays which respond to current in the motor circuit depend either upon the magnetic effect of the current directly, or upon its heating effect. Of course, the relay itself may be acted upon directly by the motor current, or where the current is high, indirectly through current transformers. The instantaneous overload relay is always magnetic in type. A field is produced by the motor current; the armature comes up immediately at the critical value and opens or closes the contact necessary for opening the controller, or it trips a latch for the same purpose.

The overload relays of the time delay type are of the inverse time type, as distinguished from definite time. They may be either magnetic or thermal. The magnetic sort is similar to an instantaneous overload relay but its armature is restrained by a dash pot or its equivalent.

The thermal type of overload relay is built to respond to the heating effect of the current. The temperature responsive element of the relay is sometimes arranged to carry the current itself; and in other forms of relays, the temperature sensitive element is indirectly heated from a resistive conductor through which the motor current flows. All thermal type overload relays are inherently inverse time delay. It takes time for a certain current to raise the temperature of the responsive element to the critical value. A higher current takes less time.

For application to small motors, the thermal overload relay is simply an inverse time current relay. For use with larger motors, there is often used, a relay operating on a temperature rise effect, in which the current-temperature-time characteristics of the active layer of the motor are imitated in the relay. Its effectiveness as a protective device, of course, depends upon how faithfully the characteristics of the motor are imitated in the relay.

All thermal relays operate on the principle that the current causes the temperature to rise to a value corresponding to that current above the ambient. It might seem that they are therefore ideal, since for a higher ambient they will arrange to disconnect the motor at a lower current, whereas a magnetically operated relay will respond to the same current at any temperature. It need hardly be pointed out, though, that this ideal will not be attained unless two conditions are satisfied, first, the ambient temperature at the location of the relay must vary exactly with that at the motor, and second, the relay must have the same current-temperature-time characteristics as the motor.

Reference has been made to one relay in which this is attempted. In that case, the relay is arranged with a certain mass, whose heat capacity is such, that with the heat developed in the relay itself, a fair imitation of motor temperature occurs. Other schemes have been used successfully to the same end—that the relay may trip the controller according to a current-temperature-time curve lying just under a similar one for the motor. Usually a simple thermal overload relay has such a characteristic curve that if it is set to protect the motor at light and heavy loads it will not give protection at intermediate values. And if it is set to permit the inrush currents especially on full voltage starting, it will not protect for usual overloads. A simple thermal relay fed from a saturable core current transformer has been one successful solution to this problem.

Another solution is a relay operating upon the combination of thermal and magnetic effects. The current acts magnetically upon an armature, which is held out definitely by a mechanical latch. The latch is governed by a temperature responsive device, heated inductively by the main circuit current. The latch is released at a critical combination of current and time, the armature goes up, and the main circuit is opened through whatever agency the sort of controller requires. Furthermore, this relay is arranged to respond instantaneously (by magnetic means) to a definite value of current. A current-time characteristic is therefore provided for values of current below a critical value; but at that critical value of current, the circuit is caused to be opened forthwith. By properly proportioning such a relay the heating curve of a motor is followed on the safe side; it permits full voltage starting, protects over the range of operation of the motor and also will cause the motor to be disconnected on single phase running at dangerous values of current. Having a temperature responsive element, it is self-adjusting as to ambient temperature; but of course within the limitations already referred to as to this particular.

The relay just mentioned provides what the industry now knows as dual overcurrent protection. In many

FIGURE 7—View of steel-enclosed switchboard built for steel plant use in a-c. system.

mills it is the practice to provide such protection on motors above a certain size. Often separate relays are used—one for the time delay characteristics, another for instantaneous action.

In setting the instantaneous element of any dual overload relay, whether both functions of dual overload are accomplished in the same or in separate devices, one must allow for the transient current. A circuit involving a motor is one consisting of so much resistance and so much reactance so far as the suddenly applied a-c. voltage is concerned. If the circuit be closed at any other than one instant on the voltage wave, the initial value of the current will be higher than the steady flow current value for the same circuit impedance. The value of the current rapidly decreases to the steady flow value, of course. But since the instantaneous relay is usually fast enough to respond to the offset current, the maximum value of that offset current must be allowed for in setting the relay. Thus a motor may have a (steady value) locked rotor current of eight times full load but to allow for the transient current, it may be necessary to set the instantaneous relay at 10 or even 12 times full load current to insure a successful start every time.

It is proper that the transient current be allowed for; it is a normal condition. Normal conditions are to be allowed; abnormal conditions are to be protected against. Normal conditions of current flow to an induction or synchronous motor include the flow of a certain current for a corresponding interval of time up to the value, including allowance for transient, of the initial inrush current. The latter is the maximum possible current the circuit can take, if everything is all right. Below that value, currents may normally be taken for certain intervals. If, for a certain current, the time it flows is too long, it is an abnormal condition, and the motor must be disconnected from the line. That is the function of the inverse time current element of the dual overload. On the other hand, if a current flow of magnitude greater than the maximum value, allowing for offset wave, it is an abnormality of at least the second degree, and it is the function of the instantaneous element to disconnect the motor from the line immediately.

This paper is concerned mainly with protection in cases of abnormal conditions. There are, of course, other conditions of abnormality which must be provided for. Mention is made, merely in passing of reversed phase rotation. It is common practice to provide a reverse phase relay and certainly in all cases where the direction of rotation is vitally important.

It was indicated a few paragraphs back, that current flow abnormalities "of the second degree" may occur in a motor circuit. And it is to such that we shall now direct our attention. So far, in considering overcurrent in a motor circuit we have been concerned with conditions where the magnitude of the current depends upon the characteristics of the motor and the degree and nature of its loading and operation. We have been

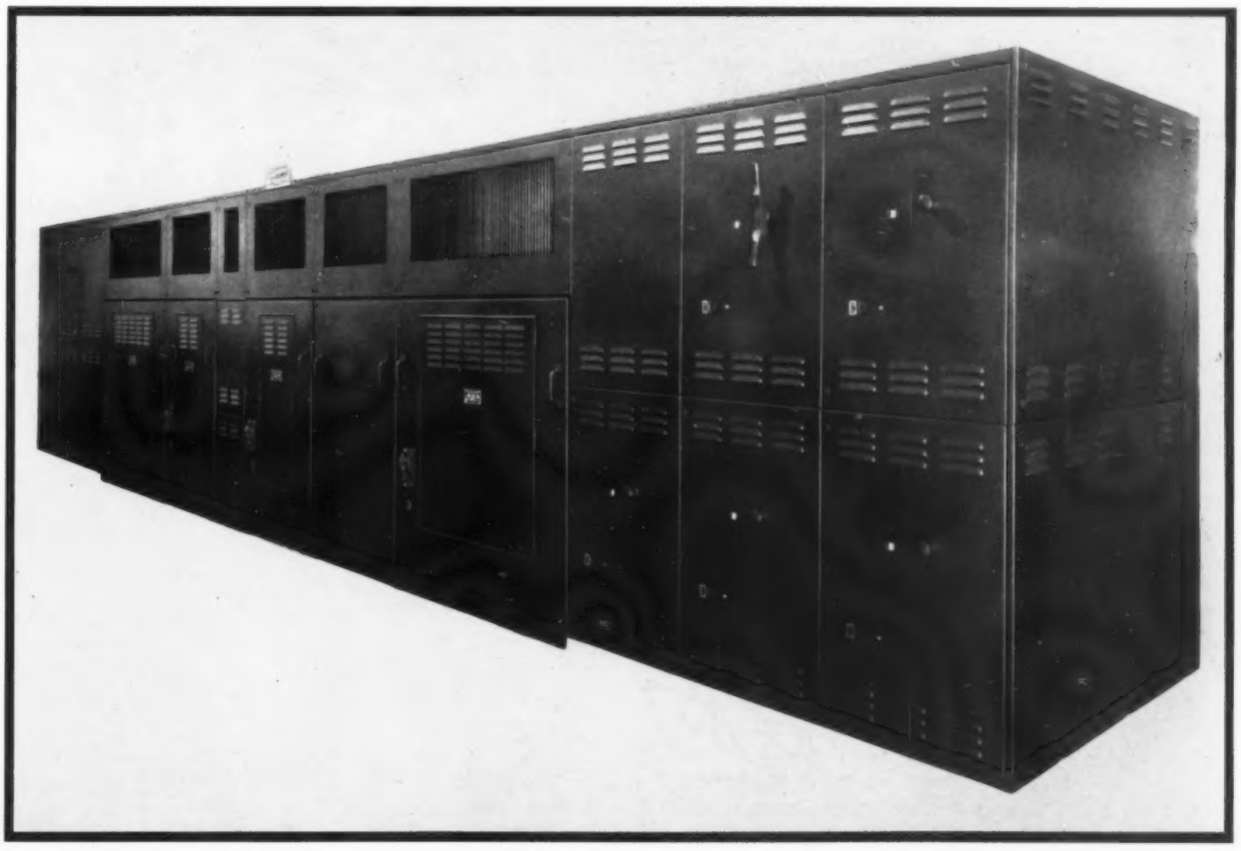


FIGURE 8—Another view of a typical steel mill installation of steel-enclosed switchboard for use in a-c. system.

dealing with a normal motor, operating from a normal circuit, but loaded abnormally. We next concern ourselves with abnormal circuit conditions—grounded motor windings, a short circuit, etc.

In the former case, the characteristics of the motor itself—its equivalent impedance under given conditions of loading—determine the magnitude of the overcurrent. Controllers for motors are built capable of interrupting the circuit under all such abnormal conditions of motor operation; and controllers are proportioned, and properly too, according to the size of the motor with which each is to be used. A controller therefore has interrupting ability sufficient to take care of stalled rotor conditions.

When, however, a fault occurs either within the motor or on the circuit, obviously, the motor impedance is not that which fixes the magnitude of the fault current. When a fault occurs, a new circuit is set up. The current that flows is the amount that the particular combination of generators, or transformers, can cause in the new circuit. The magnitude of the fault current is therefore determined by the total kva. capacity of transformers or generators or both active on the system and the impedance of the circuits from the transformers (or generators) to the fault, and upon the impedance of the fault itself. It is not determined by the size of the motor except indirectly. A small motor requires a small wire; a small wire has a relatively high impedance and therefore the fault current would be lower at the end of such a circuit than at the end of a circuit for a larger motor. For the sort of faults we now deal with we must look at the source of energy and the circuit between it and the fault to determine the magnitude of the fault current.

In interconnected systems, where there are several sources of energy, the problem of computing the magnitude of short circuit current is often quite tedious. It usually requires considerable patience and rather laborious, but not intricate, calculation. Setting up a calculating board and determining current values from it is often a worthwhile and time saving procedure. In using calculating boards, though, one must be on his guard against inaccuracies, due to inaccuracy of adjustment of each element of the calculating board. Thus if the board impedances are correct let us say to within 5 to 10 percent as to its individual elements, there may be considerable error in the indicated currents in parallel low impedance branches of the circuit fed from sources of power of relatively high sub-transient impedances. The value of the total current at the fault is affected very little, but the indicated currents in the parallel low impedance branches may be greatly in error. By this is meant errors in currents in individual branches may be of the order of 50 per cent.

But the important point is that the system should be analyzed; the magnitude of the current for a short circuit should be determined. And obviously, the device whose job it is to open the circuit under those fault conditions must be equal to the job.

In figuring the total of the sources of energy which will feed current into a fault, it is necessary to identify and total all of those sources. On the drive for a strip mill, for instance, there may be, say, four generators and perhaps six or eight motors. In case of a fault on such a system, we have to concern ourselves not alone with the four generators; but we have to consider all the motors also, as contributing to the fault current. The motors will continue to operate by inertia, each giving up its kinetic energy, after the instant the fault occurs, and in effect each motor becomes a generator and as such adds its effect to that of the real generators themselves. Likewise on circuits for auxiliaries one must include, in totalling the source of energy feeding into the fault all cases of returnable stored energy. In this class synchronous motors are the most prominent. Each will turn into a generator and tied in with the usual sources of energy will contribute its share to the fault current.

For the reasons just given the circuit to a synchronous motor is often provided with a device which will disconnect the motor from the circuit when the direction of flow of electrical energy is away from instead of into the motor. Even in such cases, the contribution each such motor makes to the fault current must be considered. For, it is to be noted the device removes the motor because the energy is flowing into the circuit from the motor. The energy is indeed flowing, and it is added to that flowing from all the other sources. The motor may be quickly removed through the operation of the reverse power relay but until it is actually disconnected, that current is a component part of the total current into the fault and it takes its part in determining the values of the currents in all the parts of circuits affected by the fault. Such currents may or may not be component parts of the current actually broken by the interrupter relieving the fault condition. This will depend upon the relative speeds of the interrupter at the fault and the disconnecting means at the motor. Usually the circuit breaker at the fault will be the faster because the accelerating force on that breaker due to the electro-magnetic action of the higher valued fault current and the motor's will be a component part of the interrupted current.

This matter of recognizing all sources of energy which may feed into a fault is an important one, and must not be overlooked if one is to avoid snake-like buses and circuit breakers overtaxed as to interrupting capacity. These inertia sources of energy are quite prominent in the strip mill but may be more difficult of discovery on a complex auxiliary system. It now seems unnecessary to specifically make this point but we shall mention that if an auxiliary be fed from the bus of a strip mill, the circuit breaker for that auxiliary should have interrupting capacity determined by all the generators and all the motors connected to that bus; it is not different from one of the main drive motors, except, perhaps, a fault on the circuit to the auxiliary may be less likely to occur and when it does, it is possible it will be of higher resistance than a severe fault on a driving motor.

Before passing from this phase of the subject it seems appropriate to mention that search for such hidden sources of energy sometimes should not be limited to the circuits of the particular voltage of the system at the fault. This depends upon how far back on the system we go in our circuit analysis. Suppose, for instance that our 440 volt circuit is fed through transformers from a 2200 volt circuit and that in turn through transformers from a 13.2 kv. circuit. Suppose, further, we aim toward an analysis of considerable accuracy,

and we analyze from the 13.2 kv. circuit down to the 440 volt taking into account, on the way, the concatenation of respective transformer impedances. Then since there is that intermediate step of 2200 volts it is reasonable to assume that there is a 2200 volt load. If that load includes such sources of energy as we have been considering, which may feed into a fault, they most certainly must be recognized as such in the computation of the fault current.

That the magnitude of the currents fed into a short is high enough to merit special attention is apparent from what has already been said. In the early part of this paper it was pointed out that even with single transformer banks as the only source of energy, the short circuit current will be of the order of 12000 amp. for a 900 kva. bank to about 40000 amp. close to a 3000 kva. bank. The device used to relieve the condition obviously must be capable of interrupting the fault current.

Fuses, as interrupters have their place. A good fuse will successfully interrupt up to about 10,000 amp. but for currents above that, fuses are not regularly available. If a fuse is applied on a circuit where the fault current is in excess of its interrupting ability, one must provide for trouble. The fuse is not unique in this respect. The same statement could be made as applying to a circuit breaker, for instance.

Comparison of fuses and circuit breakers as short circuit current interrupters may be made along these lines, although possibly the treatment will be incomplete. The fuse is essentially a single wire device. On shorts of low magnitude and of an unbalanced sort, but one fuse may blow. This would be adequate on a d-c. or on an a-c. single phase system, but on a 3-phase system, the blowing of one fuse would leave one phase alive on the system.

The circuit breaker is multipole—all poles open, and thus the system beyond the breaker is completely disconnected. The fuse on heavy fault currents blows in about the same time interval for a rather wide variation in fuse ratings. The fuse therefore offers difficulties in the matter of arranging for sequential operation of interrupters. A circuit breaker on the other hand may be made to have current-time characteristics (for currents below its rated interrupting capacity) different from other related breakers, so that selective and sequential operation of breakers is often possible.

For abnormal currents of lower magnitude such as, in this paper, we would talk of as overload currents, as distinguished from fault currents, fuses having rather definite time lag characteristics are available. Some fuses, even of the renewable type, show remarkable consistency in performance, when tested on a current-time basis. Even so, the fuse applied to a polyphase system is open to the objection that but one line is

FIGURE 9—Typical steel-enclosed switchboard for d-c. system in a steel plant.

opened when it blows, thus leaving single phase alive on the system.

Another matter worthy of consideration in fuse applications is not the fuse itself but the switch with which it is used. On some very low current circuits a fuse is used without a switch, but where currents are of any magnitude at all the hazards of such an installation should be avoided. This requires a switch, which when open, makes the fuse location dead, the whole preferably enclosed in a cabinet of adequate strength. With the switch present, the shape of the circuit may be such that on severe short circuit, considerable mechanical force is exerted on the switch in a direction to open it. This is due to the electro-magnetic action of the current. In a thoroughly investigated installation of this sort, therefore, it will be made certain that the switch is positively locked closed against the action of those forces. A knife switch is a device for disconnecting a circuit when necessary. It may interrupt currents up to a few times its continuous current rating but it is not intended as a fault interrupter and care should be taken that it is prevented from inadvertently attempting that duty.

Circuit breakers are available in interrupting capacities covering the whole range of demand. Small circuit breakers have a standard interrupting rating of 10,000 amp. (we are dealing with 440 volt applications; forms of circuit breakers of 5000 amp. interrupting capacity are available for use on 250 volt a-c. systems). The next standard step in interrupting rating is 20,000 amp. then 40,000, and then 60,000 and 80,000 amp. Air circuit breakers have been built and are available without difficulty, for still higher interrupting capacities and have been tested and successfully interrupted currents approaching half a million amperes at 600 volts.

The interrupting capacity of a circuit breaker should be considered as an essential part of its rating as well as the current it is rated to carry continuously. A proper choice of circuit breaker is based not alone upon the current it is to carry continuously but in addition, the current it may be called upon to interrupt must also be considered—that is, its interrupting capacity. Thus a breaker rated at 200 amp. continuous current, 10,000 amp. interrupting capacity would be woefully inadequate on a circuit whose continuous current might be but a fraction of the 200 amp. but on which say 30,000 amp. would flow on short circuit.

The circuit breaker may be equipped with overcurrent tripping means of instantaneous, or time delay type or with the combination of these two—the dual overload feature discussed previously. Also, of course, no voltage, overvoltage, shunt trip, reverse current and reverse power are among the conditions to which circuit breaker tripping means may be made responsive.

The dual overload feature in combination with a circuit breaker differs from the combination of dual overload and motor controller mainly in interrupting capacity. That of the motor controller is usually far below that of the circuit breaker. A magnetically operated circuit breaker equipped with the dual overload feature may therefore be used as an across-the-line motor starter; the motor receives protection by the current-time characteristics of that element of the dual overload feature, and the circuit is protected up to the interrupting capacity of the breaker by the instantaneous element of the dual overload.

Circuit breakers are made hand operated or electrically operated as conditions require. To meet some special conditions they have been made pneumatically operated.

The circuit breaker, in short, is a device either controlled locally by hand, or arranged for control from a remote point, consisting of a switch, having relatively high interrupting capacity, held closed, usually mechanically, but often magnetically or by other means, and subject to release in response to a variety of circuit conditions. Such critical circuit conditions may be caused to act directly upon the holding-in means of the circuit breaker, by means of a device responsive to those conditions, or the action may be indirect. In the latter class fall applications of sets of balancing relays or other types of relays, interlocking contacts, etc., which control the coil circuit of the shunt trip or no voltage trip, whose action in turn trips the breaker.

In thinking of the protection of an electrical circuit or device we generally think of providing against abnormal electrical conditions, and when we have arranged for the interruption of flow of electrical energy we might consider the job complete. It may not be complete. One must not lose sight of the fact that these high currents we have been talking about may give rise to mechanical forces of very high magnitude between neighboring conductors. The subject is a large and interesting one but is far too great in scope to be more than mentioned here. Its mention seems necessary though in any treatment of protection as an indication that it is a subject that must receive due consideration in any complete protection analysis. Bus runs, leads to circuit breakers, and to switchboards should or rather must be properly braced to withstand those forces. Of what value is it, to provide a circuit breaker of ample interrupting rating, perhaps in a switchboard in which buses and leads are well-braced, if when a short occurs, some weak part of the circuit collapses? Incidentally, such a collapse quite possibly would establish a new fault to ground if not line to line and call for the opening of other breakers nearer the source of energy. Such an outage would cover a wider area of load than the opening of the breaker immediately relieving the first fault.

And while this treatment of the subject is by no means complete it would be a shorter approach to completeness if the subject of circuit grounding were omitted even as to mention. It is intended to do no more than mention it, for this subject, too, is large and interesting, and incidentally controversial. There are, however, many advantages of a grounded system from the point of view, not only of circuit protection, but also from reducing the hazard to life. Now that we have mentioned the subject, we shall leave it, but with the hope that its mention may perhaps stimulate some thought on it.

A complete set of apparatus for the control of a motor, then, consists of the motor controller, overload and other motor protecting devices, and an interrupter having the required interrupting capacity and the desired features. Frequently it is possible to consider a group of motors, whose simultaneous shut down will not intolerably reduce operating efficiency. In such cases, each motor may have its own controller and the circuit of the group has one circuit breaker. Where such grouping is not feasible, or where the size of the

motors makes it advisable, each motor has its own circuit breaker ahead of the controller.

Circuit breakers having the dual overload trip are frequently applied to circuits for groups of motors. Low value overcurrents affect the current-time element of the dual overload trip. If the particular motor circuit in trouble is opened by its own overload device before the breaker trips, it only is disconnected. If, however, the overcurrent condition persists, the breaker will be tripped and the whole group taken off the line. If the overcurrent is of serious enough value to affect the instantaneous element of the dual overload trip, the breaker opens immediately, disconnecting the whole circuit.

In applying a circuit breaker to a small motor, it is advisable to consider the starter as well as the motor as a thing to be protected, and reference is made especially to the thermal overload part of the starter. Currents not greatly in excess of stalled rotor current may destroy the heating element in a very short time. In such cases, a quick-acting circuit breaker with instantaneous trip has been found adequate. Such a breaker opens the circuit in a time around a cycle.

These breakers find another application in the individual protection of runout table motors both d-c. and a-c. Due to the manner in which the runout table motors are started, the inrush current is low and the instantaneous trip of the circuit breaker may be set just above the maximum normal motor current. It is, therefore, prompt in its relief of abnormal current conditions.

The manner of mounting circuit breakers varies widely. Although cases of open type circuit breakers still exist, the tendency today is decidedly toward the enclosed type. We are thinking now especially of circuit breakers for circuits of auxiliaries.

For main mill drives a whole room may be set aside for the switchgear so that the necessity for further enclosure is not so prominent. But even in the case of main mill drives fully enclosed switchgear is being used.

Sometimes individual enclosed circuit breakers are mounted upon the wall near the motor. In other cases a group of the same sort of breaker, is mounted upon a stand, one breaker for each motor, the whole group wired into one circuit, and the circuit of the group taken through a disconnect switch. In some of these cases, the circuit breaker, equipped with dual overload of the combined thermal and magnetic type serves the double purpose of full voltage starter for the motor and (by virtue of the dual overload) motor and circuit protective device.

A construction in considerable favor today and being used in new installations is the factory built steel enclosed, dead front circuit breaker switchboard. Into the board are built the transformer breakers, the tie breaker (if dual transformer banks are used) and all the feeder breakers. All are completely bussed together with adequate bracing and all necessary interlocks, together with current and potential transformers, and relays are built into the board. The breakers are sometimes the rigidly mounted type, and again withdrawal type for transformer, tie, and feeder breakers, or a combination of both and, of course, may be either hand or electrically operated. From a feeder breaker, the circuit of but a single motor or a group of motors may be fed. The whole circuit protection, main, tie and all feeders is thus centralized at one location in a convenient and safe installation.

Within the limited scope of a paper, treatment of a subject like this cannot be exhaustive. Only the high spots can be touched upon in passing. It does seem that it is a subject worthy of further study. Great differences in actual practice certainly indicate widely different opinions. Is it possible that the old steam-drive-day adage that the steel must go through is accepted without reflection? And that only good fortune has prevented a major disaster to the very going through of that same steel?

DISCUSSION

PRESENTED BY

WRAY DUDLEY, Electrical Superintendent, National Tube Company, McKeesport, Pennsylvania.

G. A. CALDWELL, Steel Mill Engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.

W. E. WINTERHALTER, Engineer, Carnegie-Illinois Steel Corporation, Irvin, Pennsylvania.

L. F. WORDEN, Industrial Department, General Electric Company, Pittsburgh, Pennsylvania.

T. S. TOWLE, District Manager, Cutler-Hammer, Inc., Pittsburgh, Pennsylvania.

WILLIAM DEANS, Chief Engineer, I-T-E Circuit Breaker Company, Philadelphia, Pennsylvania.

WRAY DUDLEY: I feel that the subject discussed in Mr. Deans' paper is one of vital interest to every steel mill which may experience short circuits of 10,000 amperes or above on its low voltage system, and therefore it probably applies to every steel plant in this district. It is very difficult to discuss a subject such as this with any degree of satisfaction to yourself even within the scope of a paper the length of this one, and this is true even to a greater extent where you are trying to make a short discussion. However, most of us have come to the conclusion today that we must not alone protect our motors against overload, but must also take into account the magnitude of short circuit current which can develop under abnormal conditions. It means, then where we are considering the addition of a few motors to an old system, or the construction of a new system that our first problem in making a safe installation will be to determine the maximum short circuit current which can develop at each point where power is consumed, that value may be determined by calculation, or a calculating board, with a reasonable degree of accuracy and will give a better understanding of the problem than we would otherwise have. When

the maximum interrupting duty is determined and our basic circuit interrupting requirement established, we can add such other features to the breaker as may be required by the nature of the installation.

As pointed out by Mr. Deans, the circuit interrupting device is required to operate for three different types of failure, and while similar in character, the resulting current values will differ substantially in degree. The first type and the one which I presume determines the basic cost of the device, is the fault occurring from a dead short at a point where the maximum current will be developed. The second type will be those faults arising from so-called shorts or grounds either in the tap lines, the control circuit or the motor windings, and which always contain sufficient inherent resistance or reactance to restrict the fault current to an intermediate range of values. The third type of fault is the one which is with us day by day, and that is the one which occurs from overloading and which imposes only a moderate excess current on the motor. Whereas the first type of fault may develop current values of 10,000 amperes or over, the second type will develop substantially lower values, while the third may not exceed the rated current of the motor by more than a few per cent. Experience demonstrates the first type of fault occurs but infrequently, while the second and third types are encountered at some area in a large plant almost daily.

In other words, that feature of the protective device which establishes its basic cost is required but infrequently, while during the remainder of its service life the interrupting duty is relatively light. This leads us to the suggestion that it would be desirable from an investment standpoint to construct the current interrupting feature separate from the current measuring devices, in order that one interrupter may serve a group of related motors each provided with a current relay or a thermal element for individual protection.

I notice the sketches show 440 volt low voltage circuits only. I would like to ask Mr. Deans if in his experience he has found that faults on 440 volt systems have been of greater frequency and greater severity than faults on 230 volt circuits? I presume most of the steel plants today have a larger number of units operating on 250 d-c. and 230 a-c. than on 440 volts, and therefore for many of us, our attention must still be directed toward lower voltage protection. Only in modern strip mills and new installations, where it is desirable to clear out a lot of old equipment and modernize, are we going to the higher voltage systems. So there is still left in our plants a large number of 250 volt d-c. and 230 volt a-c. motors which require protection against excess current values arising from overloads and from faults which contain high resistance or high impedance in the circuit. It is to be hoped that no manufacturer will fail to consider this equipment in developing new current protective devices.

G. A. Caldwell: In the early days of high voltage power distribution the interrupting capacity of circuit breakers was of little concern since the power systems themselves were relatively small. In the steel industry with their own generating systems, any circuit breaker was satisfactory. However, as the steel industry grew along with the central station and other industries, the power requirements gradually increased

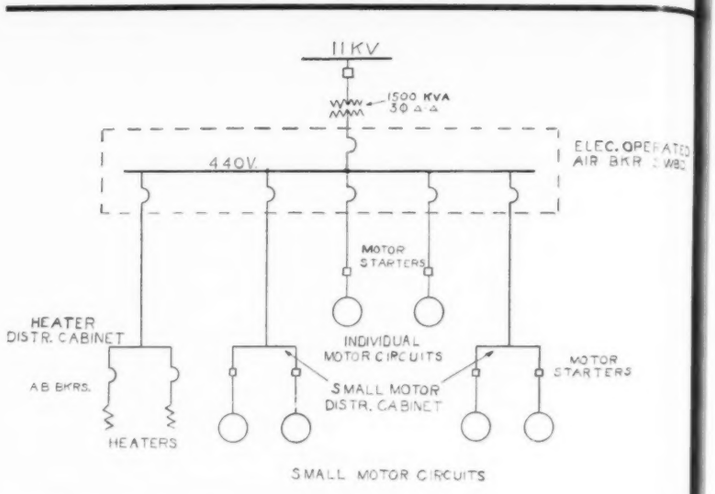
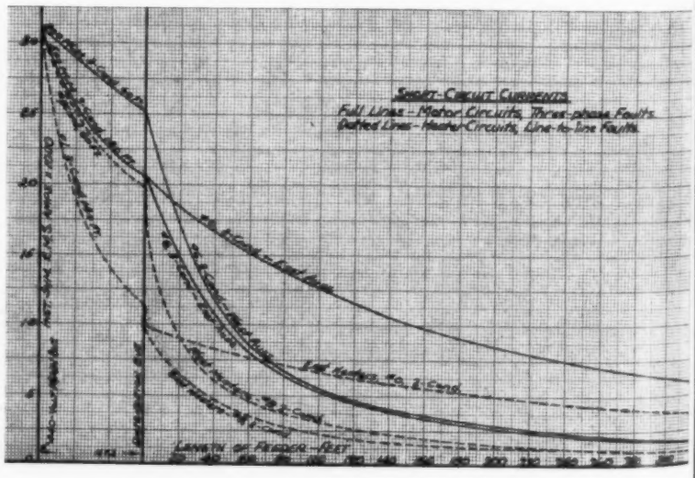


FIGURE 1—Diagram of an actual 440-volt system, showing 1500 kva. transformer bank with its switching equipment.

resulting in larger and larger power distribution systems. With the development of the interconnection of various power systems, the short-circuit currents has become tremendously large which has made a study of circuit and power conditions necessary to make the proper applications of circuit breakers.

With this development it was naturally necessary to develop circuit breakers with larger interrupting capacity and about the only way that the interrupting capacity of a breaker could be definitely determined was to apply it on a given system and then deliberately apply a short-circuit to it and find whether the breaker was capable of interrupting the short-circuit current. This method was effective and naturally resulted in a great advance in the development of oil circuit breakers.

FIGURE 2—Curves showing short circuit currents of the circuit in Figure 1, as obtained from the calculating board.



It was evident to the larger electrical manufacturing companies that the power companies could not always be depended upon to serve as a laboratory for testing their breakers, and it also became evident that some method should be developed for accurately calculating the short-circuit current that would flow at any point on a given system. The logical development of these two needs was the establishment of high power testing laboratories and of the calculating board.

At the present time, our calculating board is in a high state of development and the constants of any system can be set up within 1½ per cent accuracy of the data supplied and the short-circuit currents very definitely determined. Testing equipment is also available at our plant for testing the breakers under short-circuit conditions.

All of this development has been primarily for voltages from 2200 volts and up. Formerly most of the small a-c. motors in industrial plants were at 220 volts and the transformer banks were of sufficiently small capacity so that excessive short-circuits were not experienced. Today, however, the modern steel mill installation as well as a large number of other industrial plants is 440 volts a-c. and with transformer banks from 1500 to 3000 kva.

The calculation of short-circuit currents was usually confined to 2200 volts and higher. Of course, there is absolutely no reason why the same methods cannot be used to accurately determine short-circuits at 440 volts. Certain factors such as lead resistance which could largely be ignored on the high voltage system is a very important factor at 440 volts. At the present time when it is necessary for us to apply switching and circuit breakers to 440 volt systems, the short-circuit currents can be and are readily determined.

Figure 1 shows an actual 440 volt system of a hot strip mill showing a 1500 kva. transformer bank with its switching equipment. This switching consists of a main circuit breaker on the secondary side of the transformer and a group of circuit breakers for the various feeder circuits. Some of the feeder circuits are for motors that are located in the motor room while other feeders are used for auxiliary power out in the mill and for lighting circuits.

Figure 2 shows the results of the calculation of this circuit on the calculating board. You will note that the short-circuit current of this transformer is approximately 31,000 amperes with a solid three-phase fault directly across the terminals of the main bus. However, there is a short run of bus between the main bus and the distribution bus and so the current is somewhat reduced at the distribution bus according to the length of cable between the main bus and the various distribution buses. There are three sizes of wire that lead away from the various distribution buses depending on the load on the different branch circuits. You will note that there is a very rapid drop in current especially on the small feeders supplying power for a lubrication and grease system and other miscellaneous a-c. motors used throughout the mill. From these curves it is evident

FIGURE 3—Front view of three-pole heavy duty electrically operated air circuit breaker of recent design.

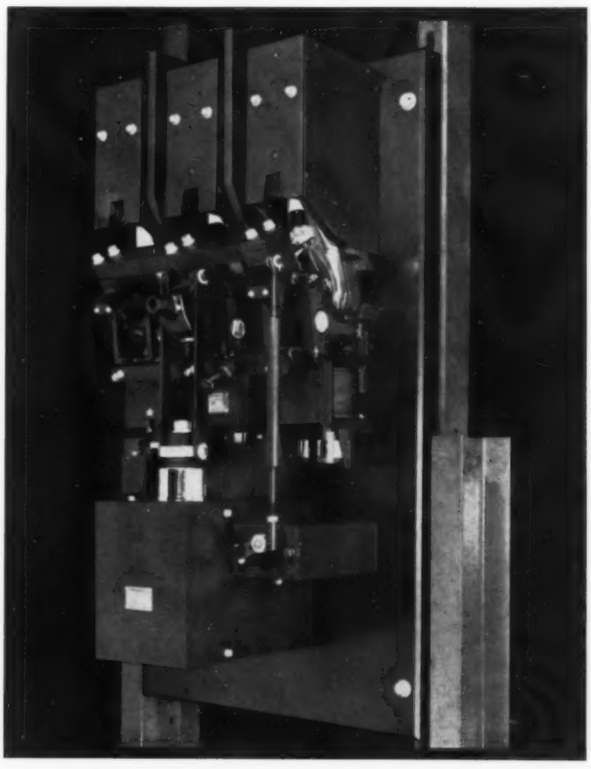
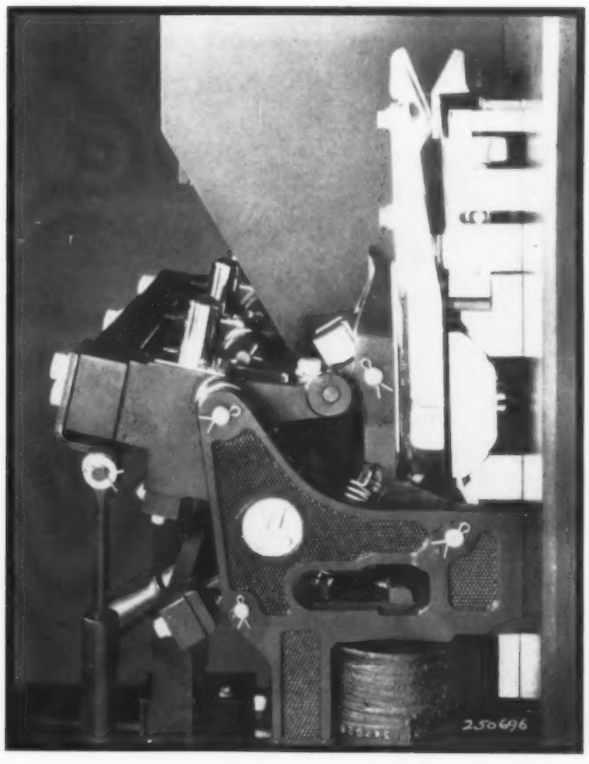


FIGURE 4—Side view of breaker in Figure 3. Such breakers are now available in high ratings for low voltage systems.



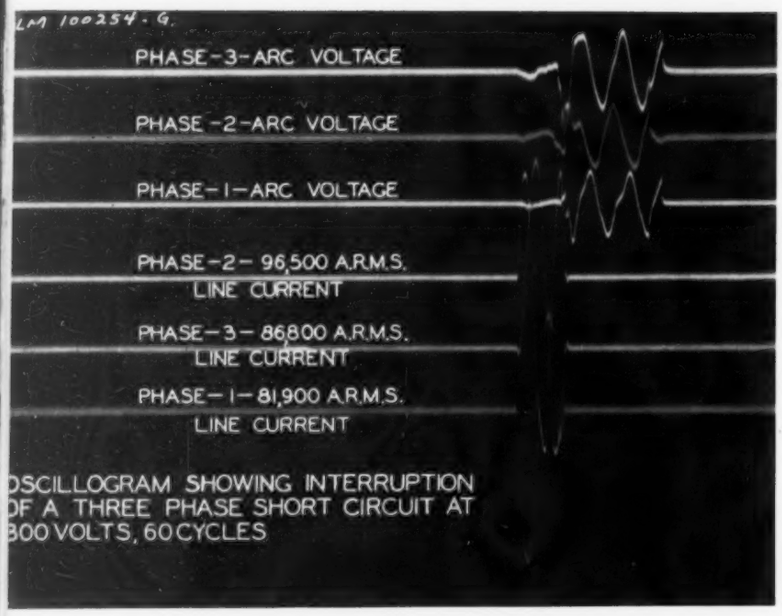
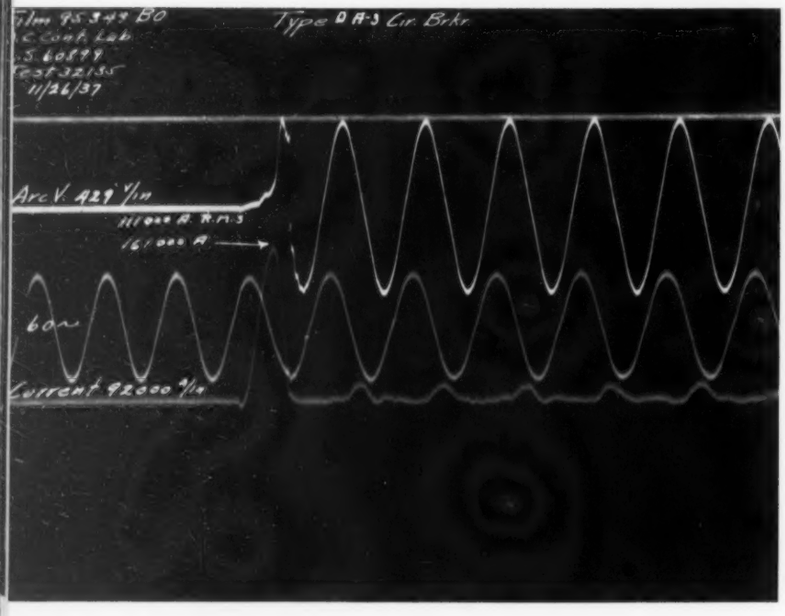


FIGURE 5—Typical short-circuit test on breaker of type shown in Figure 3, showing interruption in approximately one cycle.

that any motor located outside of the motor room and of small size will never be subjected to short-circuits in excess of 10,000 amperes and the well known combination starter with a 10,000 ampere short-circuit rating gives ample protection.

However, for the larger motors mounted in the main motor room you will note that the short-circuit currents may be approximately 20,000 amperes and therefore

FIGURE 6—Single phase short circuit test on a breaker of the type shown in Figure 3.



higher interrupting circuit breakers are required. On this particular installation all of the feeder circuit breakers are good for 40,000 amperes and the main breaker is rated at 60,000 amperes short-circuit current.

These curves are based on a metal to metal short-circuit which is practically impossible to obtain so that the curves are maximum and the value of current that would flow on the ordinary short circuit which would include the resistance of the arc would be considerably smaller than the curves indicate. With this set of curves, it is possible to tell at a glance the short-circuit current at any point in the system.

Recent development in air circuit breakers makes it an easy matter to obtain a breaker that can be rated at 60,000 amperes rms. short-circuit capacity. Breakers typical of this construction are shown in the Figures 3 and 4.

Figure 5 shows a typical 440 volt system short-circuit

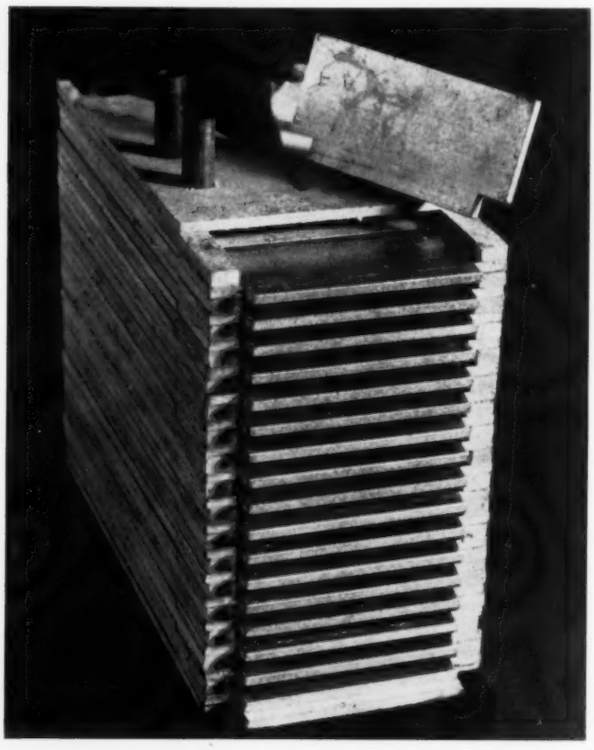


FIGURE 7—Grid assembly of the breaker shown in Figure 3. The arrangement is similar to that used on high voltage breakers.

test on a breaker of this type where the maximum rms. current on phase 2 was 96,500 amperes, on phase 1 was 81,900 amperes and on phase 3 was 86,800 amperes. You will note that this short-circuit was interrupted in approximately 1 cycle.

Figure 6 shows a single phase short where the rms. current was 110,000 amperes and the crest value was 161,000 amperes. After such a short-circuit interruption, these breakers have been reclosed and a temperature run taken indicating an increase in temperature rise of only 3 or 4 degrees Centigrade in comparison to their rise before the short-circuit is made, thus indi-

cating that the contacts were in actual operating condition after the short-circuit test.

These breakers use the well known de-ion principle that we have applied to high voltage oil and air circuit breakers and which is now available for the low voltage units. Such a unit is shown in Figure 7.

We hope by the above comments that we have conveyed to you that it is not a difficult task to accurately and satisfactorily study a low voltage distribution system, that a study is more or less a routine matter and that ample circuit breakers are available whether the short-circuit current is 10,000 amperes or 60,000 amperes. It is our own recommendation that the transformer banks be limited to 1500 to 2000 kva. in capacity and operate as a separate unit as the reduced cost of the circuit breakers will probably more than pay for the slightly larger number of units that may be required if there is no tie on the low voltage side. However, it is quite often desirable to provide a tie breaker for emergency operation in case of failure of one of the transformer banks but which is not normally closed and does not affect the short-circuit current of the system.

W. E. WINTERHALTER: Mr. Deans has emphasized circuit analysis as a basis of protection. No seasoned electrical engineer can afford to deny this subject his personal attention. Although conditions are not as bad as Mark Twain's comment on our discussion of the weather we usually don't have to look very far to find a starter rated for 5,000 amperes, spotted next door to a power source that can put from 20,000 to 30,000 amperes through it. Circuit analysis is equally practicable in averting the exorbitant cost associated with installation of 40,000 ampere control where a 10,000 or 20,000 ampere rating is ample.

Naturally a relatively small impedance is quite effective in limiting short circuit currents in low voltage circuits, but it is easy to under or over estimate its effect. To illustrate this point we may compare the per cent of normal voltage required to put 10,000 amperes through 100 ft. of several 440 volt and 6600 volt 60 cycle circuits:

			Per Cent	
			440 Volts	6600 Volts
100 ft.	500,000 cir. mils	(a) 3 conductor cable.....	13.7	.91
		(b) 2 in. equivalent spacing..	18.9	1.26
		(c) 6 in. equivalent spacing..	28.1	1.87
100 ft.	2/0	(a) 3 conductor cable.....	34.8	2.32
		(b) 2 in. equivalent spacing..	40.0	2.67
		(c) 6 in. equivalent spacing..	46.8	3.12

Much can be deduced from this summary comparison in addition to illustrating the point that rough estimates of low voltage distribution circuits can readily prove dangerous or expensive, or both; while impedances of short lengths of 6600 volt circuits do not greatly influence required short circuit ratings. Large size single conductor cables are more effective than 3 phase cables in limiting short circuit currents but may incur objectionable voltage drop when required to handle low power factor starting currents. This differential is less for small sizes as the ratio of resistance to reactance increases.

The impedance of buses, current transformers and other series equipment produce similar results.

Where calculation of these impedances would be involved it is usually possible and more practical to measure it, using a simple ammeter-voltmeter-wattmeter test.

In our experience paralleling of relatively large transformer banks through a low voltage network has presented difficulty in obtaining proportional load division between transformers and cables in addition to some increase in equipment short circuit rating requirements. We therefore prefer to operate tie lines open and close these manually or automatically for emergency service.

In many cases it has been found that separate short circuit and thermal overload relays contribute to simplicity in the relays themselves, and to economical provision of adequately rated controls. With this arrangement group short circuit protection of a number of similar feeders with individual thermal overload protection is readily accomplished.

L. F. WORDEN: The very fine paper presented tonight covers a subject which has been receiving more and more attention from both the operating men in the steel mills and the electrical manufacturers. In my own company there has been considerable research into the magnitude of short circuit currents on low voltage a-c. systems. Tests have been conducted both in the field and in our testing laboratory. Comparison of these results with calculated short circuit currents indicate that in the low voltage system the effect of resistance of the leads and the contact resistance of the circuit is relatively so high that calculated data cannot be fully trusted. Actually our tests so far on low voltage systems indicate that the short circuit currents measured on an oscillograph are considerably short of the calculated values.

Regarding Mr. Dean's suggestion on the use of air circuit breakers as motor starters, a considerable number of applications of this type have been made; however, some care should be exercised in using a latched-in device like an air circuit breaker where there are frequent starts involved. The magnetic contactor still reigns supreme in this field.

Although the number of d-c. motors used on auxiliary drives in mills today outnumber the a-c. motors in the ratio of 3 to 1, there has been an increasing tendency to use a-c. squirrel cage motors. This is particularly noticeable in many of the newer Ward-Leonard auxiliary installations, such as blooming mill auxiliaries, processing lines, cleaner and shearing lines. Here d-c. motors driven from Ward-Leonard generators are used on those drives which require accurate speed or tension control. All other drives are furnished with a-c. motors. From an overall cost consideration, motors up to and including 500 hp. should be considered for use on low voltage 440 volt systems.

Although reactor type of starting has come to be almost universally used, there are considerations, such as applications which require that a high ratio of start-

ing torque to starting current be maintained, where an autotransformer starting scheme proves more suitable. Under such conditions, if the throwover from start to run proves objectionable, the Korndorfer or continuous current method of starting is available. In this field there is an increasing interest in the use of all-steel safety enclosed low voltage air circuit breakers.

T. S. Towle: Mr. Deans has given us a very interesting and instructive paper on the protection of branch circuits for auxiliary motors and other auxiliary service, particularly as found in the steel mills. He has described many overload protective devices and has touched upon several features of overload protection which, in themselves, would provide subjects for a full evening's discussion.

We are glad to note that he has pointed out the difference between what we are accustomed to call motor overload protection and the field which very definitely calls for circuit breaker protection. He has suggested that circuit breakers with their overload trip devices can often be considered as across-the-line type of motor controllers for squirrel cage motors. This brings up one difference in the characteristics of motor controllers and circuit breakers which I feel should be given due consideration. The feature which is demanded of motor control is that of long life as well as high current rupturing capacity. Manufacturers of motor control have been devoting years of study and experiment to develop contactors that will have sufficiently high current rupturing capacity but also will give many, many thousands of operations with low maintenance, that is, long life. We believe that it is recognized that circuit breakers, being designed primarily for the interruption of very large currents, must necessarily sacrifice some of the advantage of long life and ability to act as a controller for many thousands of motor starts. It is recognized that a circuit breaker may easily pay for itself in taking care of one serious fault.

On the other hand, the contactors now used on motor controllers give high rupturing capacity, although not to the same extent as circuit breakers, but give that thing that is so very important in steel mill operations, long life and ability to start and stop the motor a great number of times. It must be recognized, therefore, that there is a very definite field for the motor controller with its overload protection and also for the circuit breaker with its short circuit protection.

William Deans: I think Mr. Dudley's question has already been answered. The answer, briefly, is that Ohm's law (applied to a-c. circuits) governs. The magnitude of the current to the fault will depend upon the total impedance to the fault and upon the voltage. A short circuit is almost never of zero impedance in actual practice; the fault usually has some impedance, itself. The effect of the impedance of the fault, in determining the magnitude of the current into the fault depends upon the impedance of the fault itself compared with that of the circuit; faults of equal impedances have less effect upon the magnitude of the fault current in circuits of relatively high impedances than in circuits of low impedances. Short circuits occurring in practice are usually from the same causes, so the impedance of a practical fault (of the same kind) tends to be the same regardless of the voltage of the circuit. Now, for the same power transmitted, the circuit impedance of a higher voltage circuit is greater than that of a lower voltage circuit. Then, for a fault on a lower voltage circuit, the impedance of the circuit is lower compared with that of the fault itself than is the circuit impedance of a higher voltage circuit, for the same sort of practical fault. Thus, on a low voltage circuit, the current to the fault is determined by circuit impedance plus relatively important fault impedance. And on a higher voltage circuit, the fault current is relatively higher being limited by circuit impedance plus less important fault impedance. Thus short circuit currents on higher voltage circuits are, generally speaking relatively higher than those on lower voltage circuits for the same sort of practical causes.

Mr Caldwell mentioned an accuracy of resistors in calculating boards as being within 1½ per cent. With such a calculating table the degree of accuracy of conclusions is higher than in the case I cited in the paper. Nevertheless even when so accurate a calculating board is used to determine the respective currents in parallel low-impedance branches it will be well to keep in mind that absolutely accurate determinations are impossible.

The opinion was expressed that readily available overload relays are inadequate for steel mill use. I submit that this may be the fault of steel mill electrical engineers themselves. It is by special study of a particular problem that its solution is accomplished. The manufacturers produce what they feel to be an adequate solution. Perhaps they do not have a complete statement of the problem. It is suggested that a committee of the Association of Iron and Steel Engineers might study such a problem to the end that the problem be quite completely presented to the manufacturers. And I feel rather sure that they will reply with an adequate solution.

Mr. Winterhalter stated that in some cases the value of the short circuit current had been determined by measurement of a relatively low current at a correspondingly low voltage on the actual circuit, short circuited. I caution you that, if there be some iron magnetic circuits excited from that circuit, the magnitude of the current on an actual short may be very much higher than that based upon such a test. The impedances due to such magnetic circuits vanish on high currents, due to saturation of the iron. So, on low voltage test on such a circuit, such magnetic circuits linked with the main circuit give appreciable impedances, but with an actual short, due to saturation of the iron, these impedances disappear as means for limiting the current. The total impedance, therefore will not include those, so the magnitude of the current on an actual short will be much higher than that determined by the ratio of actual to test voltages.

Mr. Worden and Mr. Towle called attention to the difference between circuit breakers and contactors from the viewpoint of motor starters. This is a serious omission in my paper. The circuit breaker used as a motor starter, say of the full voltage type, is not intended to be applicable interchangeably with contactors. The contactor is intended for frequent operation; the circuit breaker is not. The circuit breaker, therefore, may be properly chosen for operation as a motor starter only where the requirements call for infrequent operation. Where the service requires frequent operation, a contactor should be used for motor control and protection, and a circuit breaker should be used, in addition, for circuit protection.

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Modern PIT DESIGN and Practice at Fairfield Works

By E. A. HAWK and M. P. BURNS

Fuel Engr. *Asst. Fuel Engr.*

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Presented before the A. I. & S. E. Annual Spring Conference, Birmingham, Alabama, March 27-28, 1939.

INTRODUCTION AND HISTORICAL

▲ THE term soaking pit dates back to the early days of the steel industry when heats were small yielding only a few ingots of relatively small size. These ingots were stripped while in a partially molten condition and placed in a pit consisting of four brick walls, a hearth and a movable cover. No provision for the introduction of additional heat was necessary, as the steel contained sufficient heat to hold the entire structure at a high temperature and permit the ingots to soak or become approximately equalized in temperature before going to the rolls.

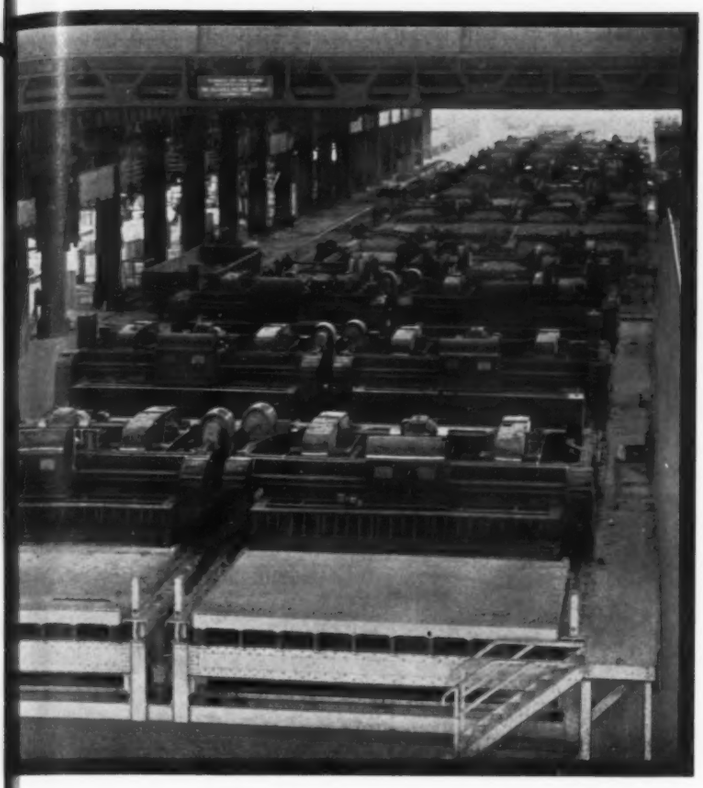
The demand for steel increased and production rates were pushed upward. The size of steel producing units was increased so that heats required more stripping time, while rolling mills were demanding higher ingot temperature. The soaking pits became a bottle neck which limited both the production and rolling of ingots. The construction of additional pits was not a satisfactory answer as the time ingots could be held at rolling temperatures was limited. The most practical way open for providing greater flexibility between pouring and rolling was to introduce fuel into soaking pits to supply any needed heat. When this was done, the soaking pit became an ingot reheating furnace, but to this day the name soaking pit is still used.

The early efforts to burn fuel in soaking pits were crude and expensive due to insufficient space for proper combustion, inadequate provision for ventilation, or any form of heat salvage. To overcome these difficulties, checker chambers, reversing valves and air inlet valves were incorporated. Thus was born the conventional soaking pit that is still largely employed by the industry—a reversing pit furnace which is fired one end at a time, with the flame travel directly around the ingots.

Such pits may give good service in the hands of skilled operators whose eyes are attuned to the light and color intensities emanating from the peep holes provided in the movable covers; but since most of the ingot surface is hidden from view, improper heating is the usual result of unskilled or careless operators. The gradual replacement of producer gas by fuels that yield more intense flame temperatures, has tended to increase the dependence that must be placed upon the human element.

Refinements have been added from time to time, but usually at some cost to basic heat economy. When combustion chambers were added they were located

M. P. BURNS



General view of installation, showing bottom-fired recuperative pits in foreground.

outside the heating chamber, thus increasing the mass of brickwork that must be kept hot, and the greater outside surface has tended to increase radiation losses. The introduction of coke oven gas, natural gas, and fuel oil into soaking pits made it necessary to use cooling water in certain vital portions of the furnace structure, to overcome the effects of the higher flame temperature, thus incurring another continuous heat loss.

Steel demand continued to grow, so that production requirements were increased. Larger ingots were needed and since existing mills could not roll a thicker ingot, ingots were made longer, and since the pits were fired at right angles to the ingots, even temperatures from top to bottom became more difficult, resulting in cold butts, uneven sections, seams and roll breakage. Soaking pits were not expanded at the same rate as open hearths and rolling mills, so forced firing in the pits was used to speed them up; resulting in washing, gas marking and white-siding. The demand for quality steel became insistent as the output of the mills was subjected to more severe usage, and the search for quality was extended from the finishing mills to the blast furnaces. Refinements were effected all along the production line. Pyrometers were brought into the mills by the metallurgists and the soaking pit became a vulnerable target and the object of much just criticism. Metallurgical research developed new and special steels for specific uses, which required careful treatment in the pits. The steel industry awoke to the fact that soaking pit practice must be improved; but how? Fuel regulation was introduced to assure a steady rate of fuel input; reversal timers were used as a general guard against excessively long reversals and many other control instruments were used to effect other improvements. The fact remained however that the heating was still no better than the heater. The human element was still the deciding factor. The only complete answer to the problem of quality heating would be reliable automatic control of all the variables that affect the quality of the work done. This was not an easy job, and to many of us, it seems impossible to accomplish economically with the old conventional type of regenerative pits. The automatic control of temperatures in the soaking pit cannot be accomplished from a single point unless the temperature of each ingot in the pit bears a definite relationship to the temperature at the point selected. The demand for quality heating, economical operation, and reliability of control has led the designers of pit furnaces to make many improvements in basic pit design.

In this paper we have been asked to discuss the six new automatic pits in operation at the Fairfield Steel Works of the Tennessee Coal, Iron and Railroad Company.

E. A. HAWK

GENERAL DESCRIPTION AND LAYOUT

The present soaking pit plant at Fairfield Works consists of four rows of reversing regenerative pits, four rows of non-reversing, direct-fired pits and three rows of bottom-fired, non-reversing, recuperative pits. The regenerative and direct-fired pits are arranged four holes to a row, while the bottom-fired pits have two holes to the row. Each row of pits has one stack with dampers

for each hole. The entire eleven rows are intended to serve both Nos. 1 and 2 blooming mills.

The ingot buggy track runs the entire length of the soaking pit building at right angles to the mill approach tables so that ingots from any pit may be routed through either mill. Ingots may be stripped at either end of the soaking pit building and brought adjacent to any row of pits on a standard gauge track alongside the pits on the opposite side from the ingot buggy track. All charging and stripping cranes are on a common runway, the stripper cranes being located at each end of the building. In ordinary practice, the molds are not stripped from the ingots until pit space is available for placing the ingots. All controls are operated from an elevated platform, in the lean-to, overlooking the pits, and are operated on signal from the heaters or cranemen.

The cinder removal tunnels below the pits are connected with a header tunnel running the entire length of the building. Cinder is taken from below the drops by wheelbarrow and dumped into an elevator bucket which in turn empties into a refuse car located outside the building. Coke breeze for bottom making is dumped from gondolas into screened pits at the ends of the building, from where it is loaded into drop-bottom buckets and carried by the charging cranes.

FURNACES

The three rows of bottom fired pits are spaced on 45′–0″ centers between refractory faced charging floors independent of the pits. The pits are rectangular in shape, having inside dimensions of 15′–0″ x 15′–0″ on center lines x 10′–4″ deep. The four steel encased walls with 18 inch refractory and 4 inch insulation are cambered 4½ inches outward to provide a firm structure. The coke bed on the structurally supported bottom of 13½ inch refractory and 2½ inch insulation is maintained between 12 inches and 16 inches in depth.

Each pit is fired from a single dry pipe burner through a circular bottom port 3 ft. 1½ in. in diameter in the center of the bottom, the top of the port extending 19 inches above the pit refractory bottom or approximately 5 inches above the coke bed. In the Fairfield design, waste gases are removed through outlets near the four corners, just above the coke bed, and pass on to four separate recuperators set symmetrically in relation to the pit. Each recuperator proper is 6′–9″ x 5′–9″ x 6′–10½″ deep consisting of octagonal sectional tubes of thin-wall and horizontal joint construction. Outside walls are steel sheeted with 9 inch refractory and 4½ inch insulation. Roofs are 9 inch refractory with 2 inch insulation. Waste gases pass down through the tubes and into collecting ducts leading to the stack. Air enters at the recuperator base through manually set slide gates and passes through a baffle system to give five criss-cross circuits as it rises to the top of the recuperator outlet and on to the burner port. The waste gas ducts are carried below the recuperators as part of the construction and extend to the stack in round refractory lined, steel flues. Two flues from the near pit join to a common 37 inch inside diameter uptake as do the two flues from the far pit. Beyond the automatically controlled butterfly damper in each flue uptake is a manually positioned mushroom damper. Beyond the mushroom dampers, the flues from adjacent pits combine to form a common flue to the stack. The self-supporting, brick-lined, steel stacks are 5′–0″ inside diameter by 100′–0″ high.

Each pit has four clean-out holes, symmetrically located for dumping cinder. Distribution of ingots per pit is usually:

16–24″ x 24″
12–24″ x 36″
8–24″ x 48″

Ingots placed adjacent to the side walls form an open and unobstructed combustion chamber in the center of the charge. The upward direction of the center flame and outward and downward flow of waste gases provide a uniform heating medium by means of radiation and convection; a portion of the cooler waste gases is recirculated with the upward travel of the flame thus increasing convection heating, which not only tends to prevent any excessive flame temperature, but also counteracts the tendency for formation of low temperature pockets. It is essential that the pit be operated under a positive pressure, not only to exclude air infiltration but to assist the flame in recirculation of waste gases, the recirculation increasing with an increase in pit pressure.

Considerable doubt developed when the pits were first put in operation as to whether combustion of the fuel gas was being completed entirely within the pit when using a vertical unrestricted 6 inch pipe burner nozzle. Experiments were made with higher fuel gas velocities which led to the development of an alloy burner insert which greatly reduced the burner nozzle opening. The primary purpose of the smaller burner nozzle was to decrease the flame length without increasing the air ratio, so that combustion would not carry out of the pit into the recuperators at high rates of thermal input. Any benefits derived from these inserts should be reflected by lower waste gas temperatures in the flues. A six-point pyrometer was installed to continuously record flue gas temperatures for a period, prior to, and following the installation of the nozzle inserts. A summary of the temperature records is shown in Table I., and indicates a definite trend downward in average as well as maximum flue temperatures. No changes of any kind were made in any of the controls during the test run, and operating conditions and rates were approximately the same. These temperatures may seem very low, but they were purposely taken on the stack side of a point where some air infiltration to the flues is permitted.

HEAT BALANCE

Table II. is a tabulation of calculated heat balances based on six divisions for ingots charged at different temperatures. Heat to steel is based on the difference between heat content at 2250 degrees F. and average temperature charged. Radiation losses are constant hourly factors, while opening losses are based on number of ingots per charge. Average temperatures of stack gases in the flue uptake agree with temperature readings at this point. Preheat temperature readings however,

are higher and more constant than the calculated preheat temperatures due to radiation from the flame and brickwork on the thermocouple located in the approach of the burner port. On the basis of actual preheat temperature readings, the efficiency of the recuperator would be abnormally high.

It is interesting to note the increase in calculated preheat temperature and increase in recuperative efficiency as fuel rates decrease. Without automatic temperature control, the fuel rate, no doubt, would be greater, the stack temperature higher and recuperative efficiency lower. The same would apply if fuel-air ratio were omitted.

As a cold steel charge becomes heated, it follows the same cycles as represented by the four remaining divisions, namely, fuel rate and stack gas temperatures decreasing, preheat temperature and recuperative efficiency increasing. In the cases of hot steel charges, radiation and opening losses show appreciable losses.

Throughout the complete range from maximum fuel rate of 25,000 cu. ft. per hr. to the holding fuel rate of 4,000 cu. ft. per hr. the calculated preheat ranges from 1300 degrees F. to 1660 degrees F. and recuperator efficiency from 51.0 to 61.0 per cent with 25 per cent excess air when using coke oven gas fuel.

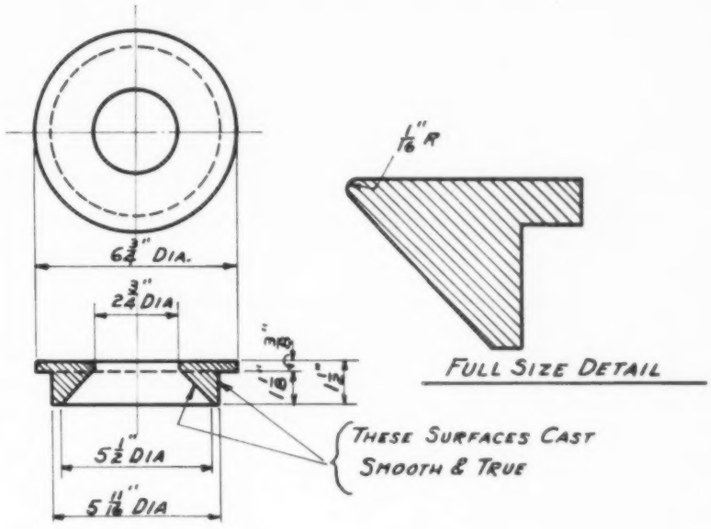


FIGURE 1—Sketch of alloy burner insert, which greatly reduces burner nozzle opening, and gives lower flue gas temperatures as indicated in Table I, below.

COVERS

Each pit has a remotely controlled cover. The cover is a flat 9″ interlocking refractory arch, with 2″ insulation. The cover is suspended by four adjustable rods attached to a lift carriage. It is encased in a heavy welded frame provided with alloy flanges to engage a sand seal trough around the rim of the pit when the cover is closed.

The soaking pit covers are operated through speed reducers by two 3-phase, 60 cycle, 220 volt motors;

TABLE I

Temperature Study of Pit Flues

Pit No.	33	34	35	36	37	38	Total
First day without burner insert	530°F.	585°F.	600°F.	630°F.	590°F.	610°F.	591°F.
Second day without burner insert	605°F.	625°F.	620°F.	700°F.	560°F.	650°F.	627°F.
Third day without burner insert	590°F.	545°F.	635°F.	620°F.	600°F.	540°F.	588°F.
Fourth day without burner insert	540°F.	635°F.	630°F.	640°F.	520°F.	540°F.	584°F.
Average 4 days without burner insert	567°F.	597°F.	622°F.	647°F.	567°F.	584°F.	598°F.
First day with burner insert	550°F.	570°F.	615°F.	570°F.	575°F.	580°F.	577°F.
Second day with burner insert	510°F.	500°F.	565°F.	570°F.	595°F.	530°F.	543°F.
Third day with burner insert	580°F.	560°F.	605°F.	600°F.	540°F.	520°F.	568°F.
Fourth day with burner insert	550°F.	560°F.	650°F.	510°F.	575°F.	585°F.	572°F.
Average 4 days with burner insert	548°F.	548°F.	608°F.	562°F.	560°F.	553°F.	563°F.
Maximum temperature without burner insert	780°F.	830°F.	815°F.	1015°F.	885°F.	935°F.	1015°F.
Maximum temperature with burner insert	740°F.	790°F.	835°F.	910°F.	845°F.	855°F.	910°F.
Average temperature drop with inserts	19°F.	49°F.	14°F.	85°F.	7°F.	31°F.	35°F.

TABLE II

RELATIVE PERFORMANCE OF AUTOMATIC SOAKING PIT WITH RECUPERATOR

24 in. x 24 in. ingot, control point 2300 degrees F., net heating time plus one hour for charging drawing. Fuel, cokeoven gas, 550 gross Btu., 500 net Btu. per cu. ft.

Ingot Color at Charge	Light Orange	Dark Orange	Red Hot	Black Hot	Cold	Average
Net tons/charge	85	85	85	85	74	85
Number ingots/charge	16	16	16	16	14	16
Time—hours	4.0	5.0	6.5	8.0	9.5	5.5
Coke oven gas—cu. ft.	40,000	55,000	90,000	140,000	200,000	68,000
Fuel consumpt. cu. ft./net ton	470	647	1059	1648	2700	800
Fuel consump. million net Btu./net ton	.235	.324	.530	.824	1.350	.400
Ratio fuel consumption	.73	1.00	1.64	2.54	4.17	1.24
Ingot surface temp. (approx.) (° F.)	1800	1625	1200	900	cold	1470
Aver. temp. ingot (° F.)	2025	1850	1425	1150	....	1700
Av. temp. waste gases to recup. (° F.)	2270	2260	2240	2220	2200	2250
Million Btu. to steel	5.95	10.10	20.65	35.90	54.75	14.02
Million Btu. pit radiation	6.00	7.50	9.75	12.00	14.25	8.25
Million Btu. to opening losses	3.00	3.00	3.00	3.00	2.61	3.00
Total requirements	14.95	20.60	33.40	50.90	71.61	25.27
Corresp. avail. heat/cu. ft. gas	374	374	371	364	358	372
Avail. heat/cu. ft. gas—no preheat	183	184	186	188	190	185
Net heat from preheat	191	190	185	176	168	187
Corresp. preheat of (25% excess air)	1605°	1595°	1550°	1480°	1425°	1570°
Mil. Btu. in waste gases to recup./hr.	3.17	3.48	4.34	5.46	6.52	3.90
Mil. Btu. to radiation from recup./hr.	.50	.50	.50	.50	.50	.50
Mil. Btu. net/hr.	2.67	2.98	3.84	4.96	6.02	3.40
Mil. Btu. to preheat/hr.	1.91	2.09	2.56	3.08	3.54	2.31
Mil. Btu. to stack gases/hr.	.76	.89	1.28	1.88	2.48	1.09
Mil. Btu. to radiation from flues/hr.	.15	.15	.15	.15	.15	.15
Mil. Btu. net to stack/hr.	.61	.74	1.13	1.73	2.33	.94
Corresp. temp. below recup. (° F.)	640	680	760	870	950	730
Corresp. temp. in flue uptake (° F.)	520	580	680	800	890	640
Heat to steel (%)	29.8	36.7	45.9	51.3	54.8	41.3
Heat to radiation from pit (%)	30.0	27.2	21.6	17.1	14.2	24.3
Heat to opening losses (%)	15.0	10.9	6.7	4.3	2.6	8.8
Heat to recup. radiation	10.0	9.1	7.2	5.7	4.8	8.1
Heat to stack gases (%)	15.2	16.1	18.6	21.6	23.6	17.5
Total	100.0	100.0	100.0	100.0	100.0	100.0
Efficiency of recuperator (%)	60.3	60.0	58.9	56.3	54.2	59.2
Aver. fuel rate, cu. ft./hr.	10,000	11,000	13,820	17,500	21,050	12,350

one 15 hp. on the hoist, and one 10 hp. on the traverse. Control is magnetic across-the-line type, and was originally mounted on the cover mechanism. Power was supplied through a 7-conductor cable, connected to a spring operated reel, which was stationary on the pit. Both motors were supplied with torque brakes. The master controls are mounted on the operator's pulpit, about 30 feet from the pits.

Limit switches are provided for limiting the travel of the cover, also interlocking the hoist through the traverse control. Some trouble was experienced with the control, due to cable failure. It was also found that it was not desirable to have the magnetic panel located on the cover mechanism, as it was subjected to considerable heat and dust. It was also impossible to locate it so that it would not be in danger of being struck by a soaking pit crane tong.

After a short period of operation, we found it was going to be quite expensive in maintenance, principally for renewing cables, and it was decided to move the magnetic panels from the mechanism to the operator's pulpit, and to install trolley wires in place of the reel. To do this, it was necessary to re-arrange the wiring and to replace one torque motor brake with a single phase solenoid operated brake. The limit switches that were originally furnished were replaced with others of the hatchway spring type. These were relocated, being installed under the floor to prevent their being damaged. Since these changes have been made, little trouble has been experienced due to control failure, and practically no maintenance has been required. However, it must be remembered these pits have been in service only a short time.

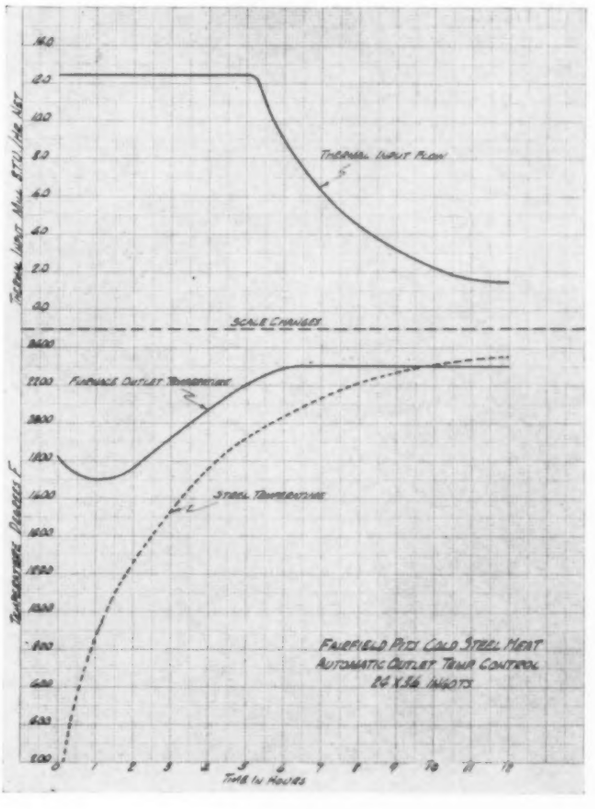
Each cover is equipped with a single line, manual lubricating system. This unit serves all bearings on the cover, including the track wheels. Considerable trouble was experienced on the installation at first, which was corrected by mechanical improvements of the lubricating equipment. Further, the equipment was subjected to an excessive heat condition which was overcome by the installation of a shield over the track wheel bearings and insulation of the feeder lines and pumps. At present the systems are performing satisfactorily. A soda base grease is used for this service.

CONTROLS

Temperature in the new pits is controlled by thermocouples located in the waste gas stream leaving the furnace. This location was finally selected after considerable experiment with temperature records made at other points in the furnace. Still further temperature studies are being made as this is written, with the idea of reducing thermocouple maintenance. The temperature at the outlets is so closely related to actual ingot temperature that it is used to automatically regulate the rate of firing. This is done by a potentiometer-controller which regulates the flow of combustion air by means of a motor driven valve in the 18 inch diameter air supply line. The pressure drop across an orifice in the air line, in turn, regulates the gas flow. The reason for having a potentiometer-controller control air flow rather than gas flow is that we use raw coke oven gas as fuel containing considerable tar, vapor, water, etc., that might cause fouling and sticking of the motor-operated valve. Also, as a matter of safety, the air should precede the gas in any closed system. The satisfactory manner in which our particular temperature control operates is, we think, a credit to the basic pit design, in that all ingots in the pit have approximately the same relative position to the source of heat.

Figure 2 in which the temperature at the outlet and the rate of thermal input is plotted against time, illustrates the manner in which the control operates. Early in the cycle, the ingots are capable of rapid heat absorption, cooling the products of combustion below the control point, so that firing continues at a predetermined maximum rate. As the temperature of the ingots is increased, the ability to absorb the heat generated becomes less and there is a rise in the temperature of the waste gases. As the control point is approached, the pyrometer-controller begins to reduce the air flow in regular increments for each degree rise in waste gas temperatures, so that thermal input is continued at a rate that equals the rate of absorption by the steel plus heat losses from the system. At the point when the steel is completely heated; at or slightly above the control temperature, the firing rate exactly equals the heat losses. The time of maximum firing and the rate of decrease will vary with the temperature and size of the ingots charged. The smaller ingots having more surface exposed per ton of metal will permit a longer

FIGURE 2—Curves of thermal input, furnace temperature and steel temperature, plotted against time.



firing at high rates with a sharper drop in thermal input rate when charged cold. This is not true however, when the ingots are charged hot, as the larger ingots have higher center temperatures for the same surface condition. The maximum rate of firing is determined by the capacity of a cold charge of fixed weight and shape to absorb heat. Very little, if any, heating time can be saved by pushing the thermal input above a certain rate early in the cycle, as the temperature control will immediately reduce the input rate if the rate of absorption by the ingots is exceeded. This fact is very noticeable if a pit is charged with only a few ingots, as the maximum fuel rate is quickly reduced, and the total heating time is not materially reduced. There has been considerable discussion recently of dual controls and some of the more recent pits are equipped with couples in the covers, as well as at the outlets. We see no need of such dual controls except where needed to protect the covers from over-heating, as we have had virtually no sweating of ingot tops with outlet control.

The air-gas regulators are designed to maintain the flow of gas to each pit in a predetermined relation to the rate of air flow, automatically controlled from furnace temperature. The regulator is equipped with two sensitive diaphragms suspended on an adjustable fulcrum. These diaphragms are subjected to the differential pressure created by orifice plates located in the air and gas lines. The diaphragms are of equal area so that when the adjustable fulcrum is in mid-position between the air and gas diaphragms, equal differentials are required for a balanced condition. The orifice in the air line is designed to produce a differential of 3.5 inches of water when the rate of flow is 155,000 cubic feet per hour, while the orifice in the gas line is designed to produce the same differential when the flow is 25,000 cubic feet per hour. The regulator causes an oil pressure power cylinder to move a butterfly valve in the gas line in the proper direction to maintain a balance between the differential across the gas orifice and that produced across the air orifice.

The fulcrum supporting the balance beam of the regulator is made adjustable, so that the ratio of air to gas can be changed by manually operating an indicator on the panel board.

Considerable difficulty was encountered in attempting to set the air-gas regulators guided by Orsat analysis of waste gas samples. There are four waste gas flues for each pit and at high flows and with a cold charge in the pit, there may be some variation in the composition of waste gases in the various flues. Further the periodic addition of fresh coke breeze to the bottom produces an irregular effect in the Orsat readings.

A simple and rapid means of adjusting and checking an air-gas ratio is to connect inclined differential gauges to the orifice taps in both air and gas lines and converting into flow by means of flow charts. This also serves as a check on the gas meter and the air flow indicator, and reduces the possibility of error to that produced by air or gas leaks on the downstream side of the orifices. The flow charts used are shown in Figures 3 and 4.

The pressure in the pits is controlled by a regulator which is actuated by a sensitive diaphragm. The space above the diaphragm is connected to the furnace by a 1½ inch line while the space below the diaphragm is connected by a similar line to an atmospheric opening at the same elevation as the furnace connection. The atmospheric connection is to correct for variations in head due to changes of temperature within the pipe connecting the regulator to the furnace.

Slight variations of pressure on the diaphragm cause movement of a pilot valve controlling the oil pressure which operates a relay valve. The relay valve controls the oil flow to and from a power cylinder which is mechanically connected to a damper in the waste gas flue. Normally, a pressure of .05 inches water is maintained in the pits at the point where the furnace pressure taps enter. When the cover is lifted for any reason, this pressure is released so that the dampers automatically close. This prevents infiltration of cold air due to stack

FIGURE 3—Flow chart showing air flow for various differentials across control orifice in air line.

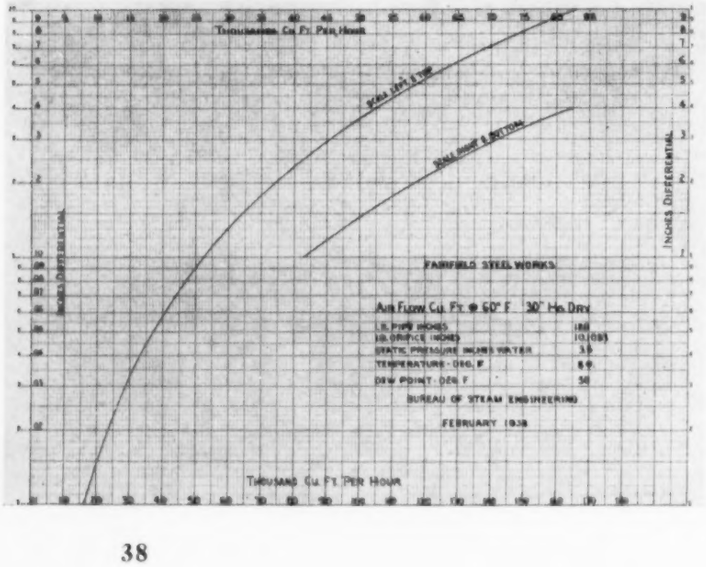
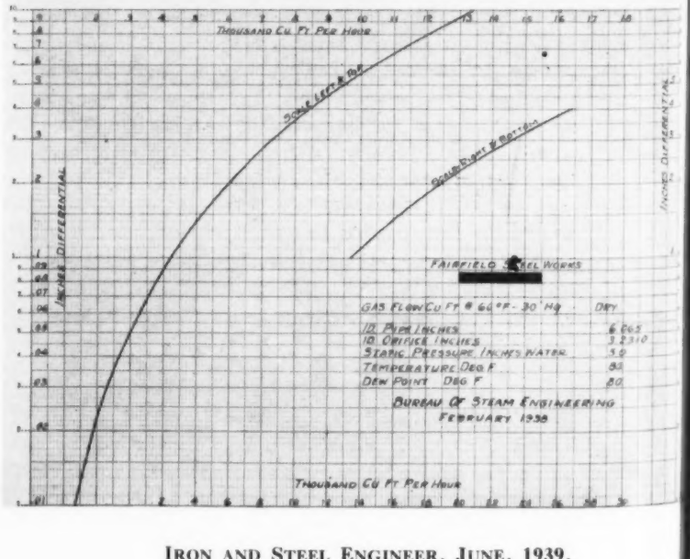

Thousands Cu. Ft. Per Hour
Inches Differential
FAIRFIELD STEEL WORKS
Air Flow Cu. Ft. @ 60° F. 30" Hg. Dry
Bureau of Steam Engineering
February 1938
Thousand Cu. Ft. Per Hour

FIGURE 4—Similar chart for gas flow. These charts are used for rapid checking of air-gas ratio.



draft during charging and drawing. During cleaning and bottom making the flow of dust into the recuperators is minimized.

The gas pressure regulator is designed to maintain a uniform gas pressure in the fuel gas supply headers to all the pits. The regulator is similar in design to the furnace pressure regulators described above, and controls the positionof a butterfly valve in the main gas supply line.

The movement of the cover automatically stops the fan which supplies the combustion air. The stop in air flow in turn shuts off the fuel gas supply. This prevents the waste of fuel during charging and drawing, and permits more efficient operation of the pit cranes which must work over the pits with the covers off.

Two oil pumps are provided to supply fluid pressure for operating the various control valves. The pumps are cross connected and normally only one pump is operated, the other serving as a spare.

All controls are provided with means for manual operation if for any reason the automatic controls fail to operate properly. Indicators for gas pressure, gas flow, air flow, furnace pressure, and furnace temperatures are provided to guide manual operation. The one thing that can shut down the pits is a failure of electric power.

FURNACE OPERATION

In operation the automatic pits are under the supervision of the regular heater who is in charge of all heating on his turn. He routes the ingots through the pits and passes on the condition of all ingots sent to the mill. At all times, however, a technically trained man with some experience in the care and maintenance of control instruments is in attendance as pit operator, and he is made responsible for the operation of all automatic controls. The pit operator is also required to keep a complete record of furnace performance on his turn. Table III. is a sample record. These records permit a

TABLE III—Sample record of complete furnace performance.

	Pit Number		36	34	35	38	37	33	37	33	34	35
	Heat Number		22068	23194	23194	21776	24865	22068	25169	25169	29802	29802
	And Heat Analysis	Carbon	.20	.10	.10	.07	.09	.20	.08	.08	.13	.13
		Mang.	.46	.40	.40	.38	.36	.46	.37	.37	.46	.46
		Phos.	.022	.083	.083	.013	.082	.022	.016	.016	.022	.022
		Sulfur	.030	.029	.029	.030	.021	.030	.025	.025	.033	.033
		Silicon	.037			Cr. .080		.037	Cr. .080	Cr. .080	.041	.041
	No. of Ingots		9	16	16	16	16	12	16	16	11	11
	Size of Ingots		24 x 36	24 x 24	24 x 24	24 x 24	24 x 24	24 x 36	24 x 24	24 x 24	24 x 36	24 x 36
	Net Tons Chgd.		77.2	86.0	85.1	86.2	83.6	100.4	85.3	85.3	95.6	95.6
Time	Finish Pouring		5:11-P	7:25-P	7:25-P	7:50-P	4:55-P	5:11-P	11:26-P	11:26-P	1:01-a	1:01-a
	Charge	Start	8:00-P	8:55-P	9:10-P	9:55-P	6:50-P	7:50-P	12:37-a	1:01-a	1:45-a	2:00-a
		Finish	8:15-P	9:10-P	9:33-P	10:10-P	7:11-P	8:00-P	1:00-a	1:23-a	1:59-a	2:15-a
	Ready to Roll		12:45-P	12:40-a	1:28-a	2:13-a	10:48-P	12:13-a	4:05-a	5:30-a	4:51-a	5:02-a
	Draw	Start	2:18-a	12:40-a	1:28-a	2:13-a	10:48-P	12:13-a	4:35-a	5:52-a	4:51-a	5:02-a
		Finish	2:42-a	1:24-a	2:10-a	3:45-a	11:44-P	12:38-a	5:50-a	6:35-a		5:29-a
	Track Time		2 Hr. 49'	1 Hr. 30'	1 Hr. 45'	2 Hr. 05'	1 Hr. 55'	2 Hr. 39'	1 Hr. 11'	1 Hr. 35'	44'	59'
	Charging Time		15'	23'	23'	15'	21"	10'	23'	22'	14'	15'
	Net Heating Time		4 Hr. 30'	3 Hr. 30'	3 Hr. 55'	4 Hr. 03'	3 Hr. 37'	4 Hr. 13'	3 Hr. 05'	4 Hr. 07'	2 Hr. 52'	2 Hr. 47'
	Total Heating Time		6 Hr. 42'	4 Hr. 29'	5 Hrs.	5 Hr. 50'	4 Hr. 54'	4 Hr. 48'	5 Hr. 13'	5 Hr. 34'		3 Hr. 29'
Temp.	Furnace Temp.	Charge	2270°	2300°	2270°	2360°	2310°	2340°	2300°	2340°	2320°	2180°
		Draw	2260°	2300°	2300°	2300°	2290°	2300°	2290°	2300°	2280°	2330°
	Control Temperature		2260°	2300°	2270°	2300°	2290°	2300°	2290°	2300°	2280°	2300°
Gas	Charge Reading	Start	0126.1	2213.2	2322.5	0799.8	97728	1750.2	9801.1	1778.4	2238.3	2349.8
		Finish	0126.2	2213.2	2323.4	0800.0	97728	1750.7	9801.2	1778.4	2238.3	2350.6
	Reading When Ready		0144.5	2233.2	2347.0	0821.1	9796.2	1775.0	9816.1	1798.7	2238.3	2363.2
	Draw Ready	Start	0144.7	2233.2	2347.0	0822.2	9796.2	1775.0	9816.1	17995	2238.3	2363.2
		Finish	0146.0	2236.8	2350.3	0828.4	9800.0	1776.2	9820.1	1802.1		2365.6
	Rate of Flow at Draw		0	6500	7500	5500	5500	5500	0	3000		
	Max. Flow-Cu Ft. per Hr.		21500	24500	23000	24000	25000	26000	24000	26000	Not Fired	23000
	Furnace Pressure		.05	.05	.05	.05	.05	.05	.05	.05	.05	.05
	Total Gas Used		61690	73160	86180	88660	84320	80600	58900	73470		48980
	Btu. per Ton		400,000	426,000	507,000	514,000	503,000	401,000	346,000	432,000		257,000
	Appear of Steel at Draw		A	A	A	A	A	A	A	A	A	A

close check on individual pit performance, and are checked against the metallurgical observers report on the condition of all ingots rolled.

It is our observation that the scale formed during the heating cycle is of normal weight, but of remarkable uniformity and texture over the entire surface of the ingots. The gradual reduction of the firing rate as the ingots become hotter does not subject the scale jacket to the thermal shock of alternate firing and dampering, so that the original scale formed goes to the mill table with the ingot. Virtually no cinder other than from coke ash, is formed in the pit so that it is not necessary to clean out oftener than once every three to four weeks. Some fresh coke is added at two-day intervals.

Table IV is a comparison in fuel consumption and rate of production between the automatic pits and the combined averages of the regenerative and direct fired pits. The comparison is arranged for two intermittent 8-hour turns and three 8-hour turns per 24-hours.

To arrive at an equitable comparison in fuel consumption, allowances should be made for different ingot temperatures at charge. Table II shows the approximate ratio of fuel consumption to be expected with different temperatures. For example, with 80 per cent ingots charged dark orange and 20 per cent ingots charged cold, the total averaging .529 million net Btu. per net ton, the practice for hot ingots may be gauged as follows:

.80 H. + .20 x 4.17 H. = .529

1.634 H. = .529

H = .324 million net Btu. per net ton

This method for discounting cold ingots may be carried further to include the five divisions from hot to cold steel charges and also for high and low carbon and special steels.

Discounting cold ingots only, as shown in Table II the comparison is as follows:

Million net Btu. per net ton

	2 Intermittent 8 hr. turns	3—8 hr. turns
Automatic pits	.501	.534
All other pits	.844	.821
Reduction	40.6 per cent	35.0 per cent

Low fuel consumption and uniform heating has featured the operation of the new pits to date. A summary of how these are obtained is listed as follows:

1. Method of fuel application, whereby sufficient combustion space is available and direction of flame travel prevents impingement of the stock.
2. Recirculation of some of the cooler waste gases prevents excessive flame temperatures.
3. Infiltration of cold air to the pit and loss of waste gases from the pit are avoided by proper sealing and pit pressure control.
4. There are no water cooling losses.
5. Automatic temperature control is not only a safe-guard against sweating ingot surfaces with the attendant increase in iron loss and bottom making, but is also instrumental in extending pit campaigns and especially life of recuperators.
6. Where fuel input is a variable, it is essential to employ automatic fuel-air proportioning to avoid high percentages of excessive air and also chances of secondary combustion in the recuperators with deficiencies of air.
7. The automatic pit pressure control not only assures proper pit pressures at all firing rates, but, in addition, reduces heat losses by closing stack dampers when pit is opened and prevents thermal shock to recuperators.
8. The transfer of heat from waste gases to combustion air is close to the source of application, thereby increasing over-all recuperator efficiency.
9. Any heating medium employing a multiple of recuperators must be checked to insure that recuperators are in temperature balance. In addition to the slide gate for distribution of combustion air to each recuperator, multiple port openings are provided below recuperator tubes. These are common to waste gas ducts and admit atmospheric air, when necessary, to correct distribution of waste gases.

The new pits have not been in service long enough to indicate the relative cost of mechanical and refractory maintenance, but all indications are that these costs will be considerably lower than in the case of our regenerative pits in similar service.

TABLE NO. IV

FAIRFIELD SOAKING PITS

AUTOMATIC RECUPERATIVE PITS

THREE ROWS—SIX PITS

1938 Period	July–Oct. Inclusive	Nov.–Dec. Inclusive
Major operation	Two intermittent 8-hour turns	Three 8-hour turns
Rows in service	3.0	3.0
Net tons per ingot	6.25	6.28
Million net Btu. per net heated	* .517	* .534
Ingots per row per turn	36.1	29.5
Net tons per row per turn	225.6	185.3
Per cent cold ingots	1.00**	.....
REGENERATIVE AND DIRECT FIRED PITS		
Rows in service	1.43	3.46
Net tons per ingot	6.30	6.42
Million net Btu. per net ton heated	* 1.119	* 1.096
Ingots per row per turn	19.6	15.4
Net tons per row per turn	123.5	98.9
Per cent cold ingots	10.2**	10.5**

NOTE: *Exclusive of heating-up cold pits.
**Ingots, other than cold, range from black to orange color hot.

DISCUSSION

PRESENTED BY

H. T. WATTS, Combustion Engineer, Republic Steel Corporation, Alabama City, Alabama.
EMIL VIEROW, Steam Engineer, Alan Wood Steel Company, Conshohocken, Pennsylvania.
L. R. KELLS, Chief Engineer, Salem Engineering Company, Salem, Ohio.
M. P. BURNS, Assistant Fuel Engineer, Tennessee Coal, Iron and Railroad Company, Birmingham, Alabama.
M. J. CONWAY, Fuel Engineer, Lukens Steel Company, Coatesville, Pennsylvania.
E. A. HAWK, Fuel Engineer, Tennessee Coal, Iron and Railroad Company, Birmingham, Alabama.
A. J. FISHER, Fuel Engineer, Bethlehem Steel Company, Sparrows Point, Maryland.
E. E. CALLINAN, Combustion Engineer, Steel and Tube Division, Timken Roller Bearing Company, Canton, Ohio.

H. T. WATTS: The soaking pits have been a thorn in the flesh since customers first became interested in quality steel. Until recently it was little more than a hole in the ground with a means for pouring in large volumes of gas and a stack utilized to draw air and remove burned gases. The space was so crowded with ingots that the fuel had to take a tortuous passage across the pit and burn in direct contact with the steel. It was not unusual to find operators deliberately producing poor quality gas in order to protect the ingots.

Nevertheless, this crude device was expected to perform a satisfactory heating operation with either cold or hot stock, two feet thick or more. As a weak link, it was blamed for every defect in the finished product which could not by a great preponderance of evidence be directly attributed to some other influence. There were complaints that ingots to the rolls were either badly burned or entirely too cold, with only a thin red line of demarcation between the two complaints, and if perchance we landed on this thin red line, perhaps the ingots were reported with cold butts and hot tops, or hot butts and cold tops. Otherwise they might be washed or have shiny faces. The old pit deserved a share of this criticism, but was doubtless blamed for many troubles for which it was not responsible.

In this paper a pit is described which apparently anticipates all of these difficulties, performing its task in a manner to forestall all criticism, just or unjust. It must have been conceived by a fellow, who over the years had grown tired of these base thrusts at the pit, with a firm determination to remove all of them at one stroke. The fortunate authors of this paper must feel that a millstone was loosed from their necks when the improved pits were installed.

SOAKING PITS

Blast Furnace Gas Air Preheat 1660 Degrees F.
Maximum Ingot Temperature 2300 Degrees F.

Size of ingot (inches)	Pounds per ingot	No. ingots charged each pit	HEATING TIME, HOURS		
			Charged cold	Charged 400-500 Deg. F.	Charged 1000-1200 deg. F.
20 x 24 22 x 24	6000 7000	6	6 7	3.5 4	2.5
23 x 28 24 x 29 25 x 30	14000	6	8	4 to 5	2.5 to 3.5
28 x 40	20000	4	8 to 9	5.5 to 6	3 to 3.5
25 x 50 26 x 50	25000 to 26000	4	8 to 9	5.5 to 6	3 to 3.5
31 x 50 32 x 50 33 x 50	28000 to 30000	3	10	6	3 to 3.5

On these pits the bottoms are made every 12 days and during this time they are sprinkled with coke to freshen them up every third day.

On the old pits using gas producer gas, bottoms must be made every third day.

A. J. FISHER: There is little argument against automatic control of soaking pits, since it makes for greater uniformity of heating, lessens scale loss, and guards against washing of the ingots.

The reference to fuel rates in Mr. Hawk's and Mr. Burns' paper is for very short periods of time, and no mention is made of repair costs. These two items, of course, should be the prime determining factors in the kind of pits to be installed.

There are two general classifications of soaking pits; regenerative and recuperative. Generally speaking the lower Btu. fuels, 100 to 150 Btu per cu. ft., are best suited to regeneration, while the higher Btu. fuels such as coke oven gas, natural gas, and oil are best suited to recuperation; although either kind of pit may be designed for any of the fuels.

If the plant fuel balance is such that blast furnace gas can be used in the pits, the plant is fortunate indeed as this is the ideal pit fuel.

My experience has been with the regenerative pit of which we have 14 rows of 4 holes each originally fired with producer gas and later changed to mixed blast furnace and coke oven gas of about 125 Btu. per cu. ft., and 8 rows of 4 holes each designed for blast furnace gas of 100 Btu. per cu. ft.

Of course pit performance is relative to the kinds of

steel heated and is not strictly comparable between plants. However, our plant is quite diversified, having more than the usual amount of pit and bottom poured ingots which are charged into the pits with a surface temperature of about 1000 degrees F.

The drawing temperature of ingots will average between 2300 to 2400 degrees F. and there is rarely a case of a washed ingot.

The fuel consumption of these pits based on gross tons and gross Btu. is as follows:

Year	New Pits	Old Pits
1937	1,167,750	1,225,800
1938	1,170,450	1,248,750

The average maintenance cost for both the old and new pits for the years 1937 and 1938 was $0.021 per tons of ingots heated. The total ingots heated for the two years was 3,723,000 gross tons.

EMIL VIEROW: I'm sure that most of us share the enthusiasm that these men have expressed for the recuperative soaking pit as against the regenerative when using high Btu. fuels such as natural gas, coke oven gas and oil because of the better flame control obtainable. Opinion is still divided in the case of low Btu. fuels such as blast furnace gas and low heat value mixed blast furnace gas and coke oven gas with which, as explained by Mr. Fisher, the resultant flame temperatures are inherently within safely controllable limits. But here again I believe that those of us who have experienced the improved design possibilities and the simplicity of both construction and operation of recuperative furnaces compared with regenerative furnaces would favor the former except of course where physical conditions interfered.

I should also like to compliment Mr. Watts on his remarks reviewing the progress made in soaking pit design and operation and regarding the place of the modern soaking pit in improving general plant technology. It is becoming more generally recognized that the remarkable improvement in heating in a comparatively few years has been a great influence in the remarkable improvement in many other plant operations. Only a few years ago there was a general tendency to blame heating for almost any and every trouble and let it go at that. The introduction of modern heating furnaces and soaking pits with automatic controls greatly improved the quality of heating but in most cases did not prove to be a "cure-all". However, with the question of heating removed from the picture other departments were forced to improve their own practices. It is difficult to evaluate the importance of unquestioned quality of heating in this respect, but it is interesting to note that those plants that are best in heating performance are also best in steel plant operation in all its phases.

L. R. KELLS: It has been my pleasure to go over the paper and to note particularly the complete record that is kept of each ingot heat. There is one question I want to ask. Since the installation of these pits, have you noticed any improvement in the operation of your old pits? In other words, in getting a standard to work by, has the standard of heating up in the old pits been raised.

M. P. BURNS: Naturally that would be more or less a question of opinion, since we don't have any actual record, but my opinion is that the new pits have put the heaters on their toes.

M. J. CONWAY: There are two questions I would like answered which will add to the information contained in the paper: What difference, if any, is there between the mill defects produced on the ingots heated in the new controlled recuperative pits as compared with the old style regenerative pits?

I would also like to know whether the heating time in minutes per inch of ingot thickness is substantially the same in both the recuperative and regenerative pits and if the rate of temperature rise follows the same curve as shown with the paper and was obtained from the recuperative pits?

E. A. HAWK: In answer to Mr. Conway's questions, the new pits will heat cold ingots just as fast, if not faster than the old regenerative pits.

In the matter of uniform temperature, I think the next step is to plot the temperature of the slab and compare that on a regenerative pit, with one of the automatic pits. I think there is quite a difference in the uniformity between the regenerative and the other type of pit. I know of some cases where they have taken temperatures, and there is quite a drop with the regenerative type.

M. J. CONWAY: Your reply does not answer the question on mill or ingot defects. At Coatesville, we roll our plate directly from a bottom poured ingot without intermediate slabbing, so that ingot or heating defects are a factor with us, more so than they are with you as we naturally want to keep our slab production to a minimum whereas slabs are the finished product of your particular mill.

I am interested to know if you had noticed a pronounced difference in heating defects between the regenerative and recuperative pits?

M. P. BURNS: In the matter of defects, we get more or less perfect heating from all the pits—"sometimes". The only difference is that the automatic control removes the "sometimes". There is less chance and actually less poor heating from the new pits than from the old pits. The new pits do not depend upon how the heater felt or what he had for supper before he came out to work that night.

The only defective heating in the old pits occurs when the human element fails. They can do perfect work, but if the human element isn't all there at that particular time, we may get corner marking, a little sponginess or may drop the scale, and while this does not occur too frequently it does happen with the old pits, but to my knowledge it never happens on the new pits.

A. J. FISHER: I might throw a little further light on Mr. Conway's question. There are two schools of thought on the heating of ingots. One is that the ingots should be heated in a reducing atmosphere—that is a deficiency of air; and the other is that the ingots should be heated in an oxidizing atmosphere.

The reason for those two schools of thought, as I understand it, is that one wants to scale the steel heavily, and in so doing a good many of the surface

defects are scaled off. That is the primary purpose of the oxidizing atmosphere. The mills that have slabbing mills, strive for heating economy in heating the ingots to the highest possible temperature. In this manner a good many of the surface defects are welded during rolling. The large scabs, etc., are burned out of the slab before the last passes are taken, and in addition, the slab may be cold scarfed before reheating for plates or other rolling.

E. E. CALLINAN: In determining the benefits to be obtained from a pit of new design and with a different type of combustion system, two kinds of comparisons must be made. One is the comparison with the pits which the new design is replacing or supplementing. The authors have presented a very complete comparative analysis of this kind. But when considering a pit which provides new applications of combustion principles you also want to know whether these new features, the new method of fuel introduction, the different flow path of the gases, and their ability to give maximum and optimum heat transfer and distribution, are an improvement over the other types of pits.

In this case much depends on what the pit is compared with. For example, Table IV compares the new pits producing an average of fifteen ingots per hole per eight hours with a row of four holes which have an average production of four ingots per hole per eight hours. There is one stack for each four holes and we know nothing about the amount of insulation, size and design of checker chambers, how much automatic control is used, and whether a tight sealing vertical lifting type or a very leaky cover is used. In addition, since the new pits are so economical, they may be receiving preferential treatment in regard to charging capacity and delay time between charges.

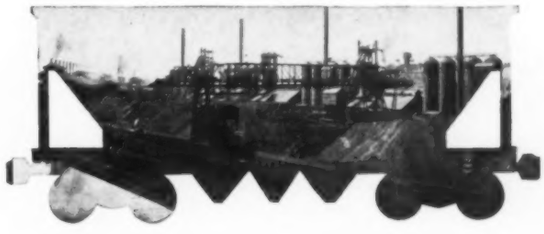
Therefore, in order to make an accurate comparison of combustion and heat transfer systems it is not correct to compare a ten year old regenerative pit which might be uninsulated, have a leaky cover, no automatic control equipment, poorly designed checkers, etc., with a new recuperative pit which in addition to its new combustion principles, has the latest conventional improvements.

The second comparison should be between the new recuperative pit and a new regenerative pit in which is incorporated all the conventional design improvements of recent years. Along with this performance comparison one naturally must include a comparison of capital costs, depreciation charges and maintenance. A comparison on this basis will determine the true advantages of the new combustion system.

In our works we have installed one of these new pits, which is performing very satisfactorily. However, we are heating radically different types of steel, have ingots of different size and design, and our regular regenerative pits evidently are of much larger size than those described. These and still other differences change profoundly the results obtained when making a comparison similar to that presented by the authors. By studying the data they present we have been better able to understand why we have obtained in some respects more, and in others, less benefits than they report. Presentation of similar data on pits operated under other sets of conditions would be of great value to all pit operators.

At this time, I believe it proper to enlarge upon the item of surface quality of the heated steel. At our works, we produce several hundred different types of alloy steel ranging from .06 to 2.00 carbon, having from low to as high as 45 per cent alloys. Some of these steels require complex treatment not only in the pits, but before and after heating. A pit from which an accurate history of a heat treatment can be obtained, and in which the treatment can be duplicated month after month, not only enables the operator to produce satisfactory quality from that pit but also enables him to determine the correct treatment and apply it to his other pits, with the result that quality of the products of all pits is improved.

From the quality standpoint, I believe, one of the most important statements made is, "the automatic control of temperatures in the soaking pit cannot be accomplished unless the temperature of each ingot in the pit bears a definite relationship to the temperature at the point selected". The pit which does this will be the most accurate in determining correct heat treatment and insuring consistent repetition of the process.



"We plugged a "Money-leak" in our Cotton Ginning Plant by installing BUSS Super-lag FUSES"

ELECTRICIAN *James B. Howard*
SAN JOAQUIN GINNING CO., EARLIMART, CALIF.

Check these Facts!

Mr. Howard still speaking; "When we built our cotton ginning plant at Earlimart in 1936 we installed regular 400 ampere fuses, the maximum size allowable, in the main switch. During the season (1936) we were handicapped by frequent blowing of these fuses due to current surges caused by the cotton pressing machines being forced too hard.

"These shutdowns, sometimes occurring as often as twice in twenty-four hours closed down the entire plant, stopped machinery, ventilation blowers, etc., and left workmen standing idle.

"In the Fall of 1937 installed BUSS Super-Lag Fuses to the great satisfaction of all concerned. They really "plugged this money-leak" for we haven't had a main fuse blow since."

BUSS

ADVERTISING PAGES REMOVED

New Coke and Blast Furnace Plant

GREAT LAKES STEEL CORPORATION

By Product COKE PLANT

At Hanna Furnace Division

Great Lakes Steel Corporation

By C. P. BETZ and P. C. VETTER

Great Lakes Steel Corp.

ECORSE, MICHIGAN

▲ THE new 130 oven by-product coke plant of the Great Lakes Steel Corporation is located on Zug Island which lies off the north shore of the Detroit River about six miles west of the downtown section of Detroit, Michigan, and three miles east of the steel plant located in Ecorse.

Due to the limited space available for the construction of a plant of this size, careful consideration of plant layout was required. The result is a very compact plant which has proven very advantageous from an operation viewpoint. The plant consists of two 65 oven batteries, by-product department, benzol plant, coal and coke handling systems and coal storage yard.

C. P. BETZ

The ovens, coking at a rate of 1 in. per hour which is considered the most economical operation, will carbonize 3300 tons of coal per day and produce sufficient coke to supply the present blast furnace demands. The foundations, flue systems, stack location and recovery equipment were constructed so that ten additional ovens could be built onto each battery which would enable us to produce coke sufficient for the operation of three one thousand ton blast furnaces.

Due to the advantages of water shipments over rail, the problem of unloading coal boats, putting coal into stock and reclaiming was one of considerable proportion. The layout we have was developed by the Great Lakes Steel engineering department and has proven very economical and efficient.

In order not to delay self-unloader boats which have an unloading rate of 1200 tons per hour, we constructed a 7000 ton steel coal bin adjacent to the Detroit River. This necessitated the building of a dock which is 405 feet long and of cellular type construction. On account of ground conditions, 90 foot sheet piling was driven in the formation of the cells.

The coal is discharged from the bottom of the bin through a series of gates. A self-propelled traveling shaker feeder is spotted under the desired gate and the coal is fed to the 42 in. conveyor system which has a capacity of 600 tons per hour to the storage yard, or at a rate of 500 tons an hour to the coal preparation system.

Coal to the storage yard at a rate of 600 tons per hour is transferred to a self-propelled stacker having an 80 foot boom and which can travel the entire length of the yard, i.e. 1200 feet. The coal can be unloaded on either side of the stacker runway and is spread and rolled in three foot layers by means of a bull-dozer to a height of 40 feet. Storage space provided will stock approximately 400,000 tons of coal which will enable us to run on stock coal during the closed season of navigation. A duplex track hopper adjacent to the coal bin allows us to unload rail coal onto the storage yard conveyors if necessary.

Provisions have also been made to unload rail coal at the coal preparation plant through two duplex track hoppers equipped with electric vibrating feeders and

discharging the coal direct to the coal handling system. A car haul is used for moving the cars.

Coal from storage is loaded into two self-propelled hoppers equipped with shaker feeders which discharge the coal to the 42 in. belt conveyors and then transfer the coal to the preparation plant. The traveling hoppers are mounted on the stacker runway and can be located anywhere along the length of the coal piles.

These hoppers are loaded by means of a diesel operated tractor-type crane using a four cubic yard bucket and is capable of transferring coal at a rate of 450 tons an hour swinging through a 40 foot radius.

The coal preparation system has a capacity of 500 tons per hour and can receive coal as shown from four sources, i.e. from the 7000 ton bin, the single track hopper, the coal storage yard and from the double track hoppers; all of the material being conveyed by belts.

The coal from the above sources is carried to two 12 x 17 breakers and reduced to a minus 1½ in. size. Bone and refuse coal which passes over the screens is conveyed to a storage bin, loaded into railroad cars and used for locomotive fuel. From the breakers the crushed coal is conveyed to the top of four 400 ton mixing bins, the coal being discharged to the proper bin by means of a shuttle conveyor.

Three kinds of coal are now being used; 25 per cent Pocahontas, 25 per cent Freeport and 50 per cent Elkhorn. One bin is used for each of the Pocahontas and Freeport coals and two bins for the Elkhorn. At the bottom of each bin there is a mixer belt, the proper volume of each coal regulated by the depth of coal on the belt. These mixer belts transfer the coal to a conveyor which feeds the coal to two reversing type hammermills where the mixed coal is pulverized so that 70 per cent passes through a ⅛ in. screen.

From the hammermills the coal is conveyed to a 3000-ton storage bin divided into five compartments and located above and between the two batteries. The coal is drawn from the bottom of these bins through three electrically operated cut-off gates into a three hopper gantry-type oven charging car.

As mentioned in the construction of the coal bin, the ground conditions on Zug Island necessitated the driving of piles wherever load conditions were of any consequence. Due to this condition, it was decided to construct the basement type foundation for the coke ovens. Wood piles 75 to 80 feet long were driven down to hard pan and the basement floor, a pad three feet thick, was laid on top of these piles. Five longitudinal concrete walls 10 feet high support transverse beams on top of which was laid the oven floor or pad, 12 in. thick.

The ovens are 15½ in. wide on the pusher side, 18½ in. wide on the coke side, thus having a taper of 3 in. They are 42 ft. 9½ in. long, face to face of doors,

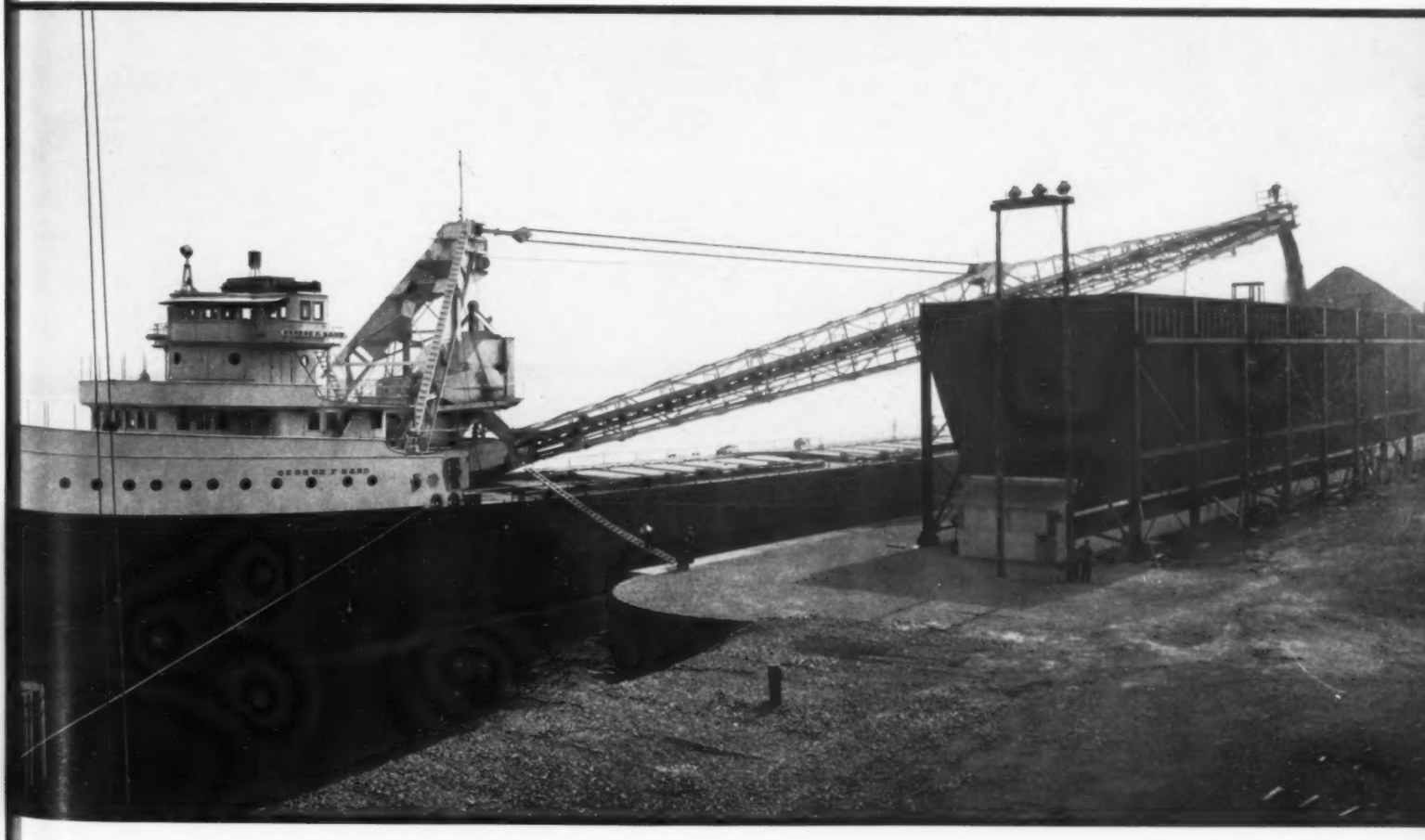


FIGURE 1—View of self-unloader boat discharging coal into 7000 ton dock bin at a rate of 1200 tons per hour.

13 ft. 5½ in. high with a coal height of 12 ft. 5 in. taking an 18 ton coal charge.

The ovens are arranged for either coke oven gas or blast furnace gas underfiring and so laid out that any group of ovens can burn coke oven gas while the balance can burn blast furnace gas.

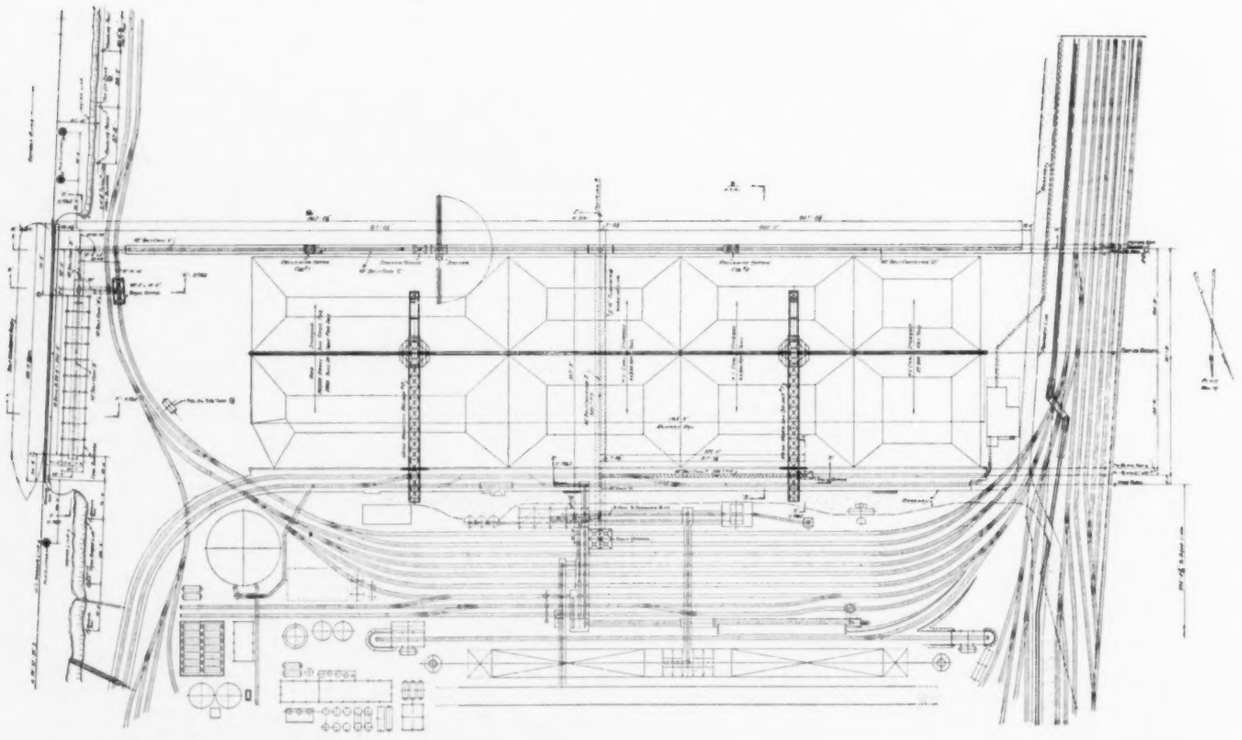
The heating wall between the ovens is composed of 28 vertical flues divided into four zones of seven flues each with a horizontal flue connecting each pair of zones. Four regenerator chambers are located under each oven and are connected to the four zones of the heating flues. One gas gun or duct is connected to each zone of flues for burning coke oven gas. Two of these guns are located on the coke side and two on the pusher side. Fire clay nozzles inserted in the gun are utilized for distributing the gas to the vertical flues.

The regenerator chambers are connected to the reversing valves by means of sole flues so that each oven has two reversing valves of the Siamese type, one located on the coke side and one on the pusher side. They are so arranged that blast furnace gas and air are taken in on the pusher side while all the products of combustion pass out on the coke side or vice versa.

Numbering the four heating zones 1, 2, 3 and 4 from the pusher side, the cycle of firing with coke gas is as follows: with gas burning on zones 1 and 3, the air enters the reversing valves on the pusher side through the sole flues, up through the regenerators to the flues while coke oven gas is supplied through the nozzles at the base of the flues. The products of combustion

C. P. Betz, superintendent of the coke plant, points out some unusual features during the inspection trip through the plant.

FIGURE 2—General arrangement of coal storage yard, which is equipped with a self-propelled stacker with an 80 ft. boom.



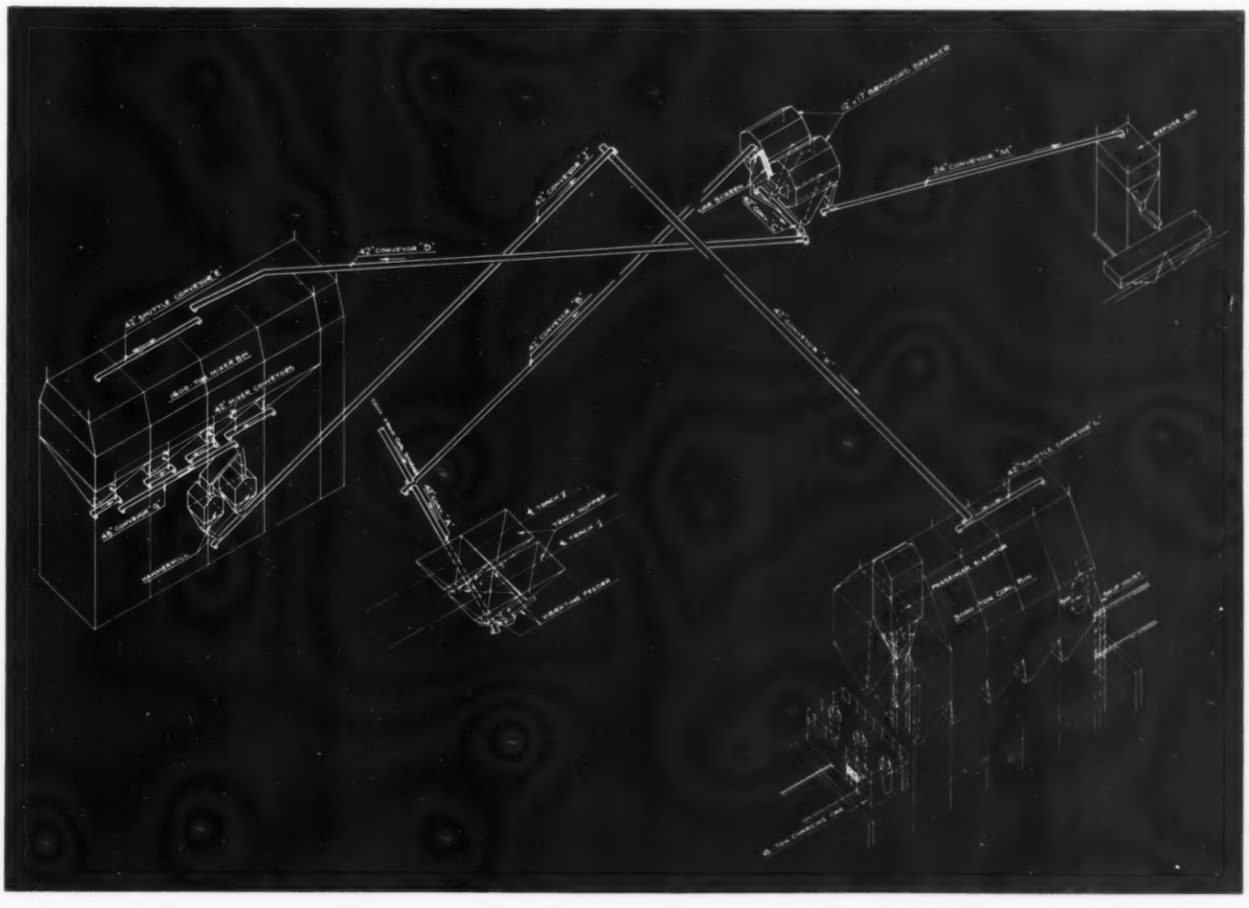
B. M. Stubblefield and H. B. Pearson, Jr., were among the interested visitors to the plant.

travel across the horizontal flues down through the vertical flues of zones 2 and 4, through the regenerators and thence through the sole flues to the stack flue on the coke side. At the expiration of 30 minutes, the gas is reversed and burns in zones 2 and 4 and the products of combustion pass out through zones 1 and 2 to the stack flue on the pusher side.

The coke oven fuel gas is slightly superheated by means of a shell-and-tube-type heater using 150 lb. steam. The fuel gas mains extend the length of the battery on both the coke and pusher side and are insulated to prevent condensation in the mains. Provision has been made for diluting the coke oven fuel gas so that if desired the coke gas for underfiring the ovens can be diluted to 450 Btu. with blast furnace gas. Experience in high oven practice indicates it is much easier to obtain uniform wall temperatures in ovens as high as 13 ft. 5 in. with diluted fuel gas.

The blast furnace fuel gas main extends the entire length of the battery with tie in lines around each end of the battery thus forming a complete loop. In previous installations, this main was buried underneath the floor, but due to the difficulty of detecting gas leakage with this type installation the main at Detroit is

FIGURE 3—Sketch showing flow diagram of coal preparation system, with a capacity of 500 tons per hour.



supported above the floor adjacent to the coke gas main. A blast furnace gas enrichment device has been provided to enrich the blast furnace gas with coke gas, and at present, is being enriched from 90 Btu. to 96 Btu. for underfiring the ovens.

Reversing machines, decarbonizing machines, control for the above mentioned enrichment device and all oven instruments are located in an instrument room between the two batteries at bench level. Continuous recording calorimeters were installed to record the Btu. value of blast furnace and coke oven fuel gas as well as the surplus coke gas. All gas flows and pressures are measured by recording instruments. Coke oven fuel gas and stack pressures are regulated by electrically controlled butterfly valves.

The ovens are provided with self-sealing doors seating on a removable door frame. The doors are handled on the pusher side by a door jack mounted on the pusher machine. There are two pushers, one for each battery, but one pusher can handle both batteries in case of an emergency when one machine is down for repairs. The pusher rail is a low 175 lb. crane rail.

There are two spring mounted, eight wheel, gantry-type, three-hopper coal charging cars; each hopper being equipped with an adjustable measuring device, drop sleeves and sliding gates. These gates are individually operated and inter-locked with the charging car travel so that the car cannot be moved while the drop sleeves are down. The coal bin gates, previously mentioned, are also interlocked with the car so that the latter, as it is being filled, cannot be moved while the bin gates are open. The charging car is equipped with recording type scales and the coal bin gates are electrically operated from the cab of the car.

The coke side door machines mechanically remove the self-sealing doors and turn the doors 90 degrees and elevate 15 inches to facilitate cleaning. They then replace and lock the doors after the coke has been pushed out of the oven. A limit torque device regulates the power applied to the door screws.

The trailer type coke guide is equipped with a racking-in device so as to set the guide back in against the door frame while pushing and prevent coke spillage. There are two door machines and three coke guides.

Two quenching cars of welded under frame construction with cast iron liner plates and air operated gates are provided together with two 20 ton electric locomotives. One locomotive and car can handle all of the coke produced while the other set is used as a spare.

The quenching car, coke guide and pusher machine are electrically interlocked so that all machines must be located at the proper oven before the pusher ram can be moved forward and the forward movement of the ram can be stopped at any time by the quenching car operator.

Two quenching stations were installed, one at each end of the quenching track. The quenching towers are 70 feet high with structural steel framework and corrugated transite siding attached to the inside of the framework. The quenching stations utilize waste water from the by-product plant liquor coolers and the water drained from the car is not recirculated. There is sufficient pressure in the water from the coolers to convey it to a 12,000 gallon quenching tank mounted overhead at these towers, with water level indicator to show the quenching locomotive operator the water level in the tank. The quenching water control valve is electrically operated from within the cab of the locomotive using an automatic timer so that the amount of quenching water used depends on the setting of the timing device. This water is applied through perforated pipes extending transversely across the quenching car and the supply header is provided with a quick draining valve. The water from the car is drained to a reinforced concrete sump, provided with baffles to settle the coke breeze and the water overflows to the sewer.

The coke wharf is 200 feet long and brick lined. The flow of coke to wharf belt is controlled by means of finger gates operated from a walkway running the length of the wharf and located over the wharf belt. A track hopper and conveyor discharging onto the north end of the wharf belt provides a means of re-screening stock coke through the coke preparation system.

From the wharf the coke is conveyed by a 42 in. belt to the coke screening building having a capacity of 175 tons per hour and is arranged to produce foundry, furnace and domestic coke. The screening station is very flexible, by-pass chutes being provided at all screens so that in the event of a screen failure, the coke can be by-passed to another set of screens. All equipment is controlled from a central station located at the furnace loading boom.

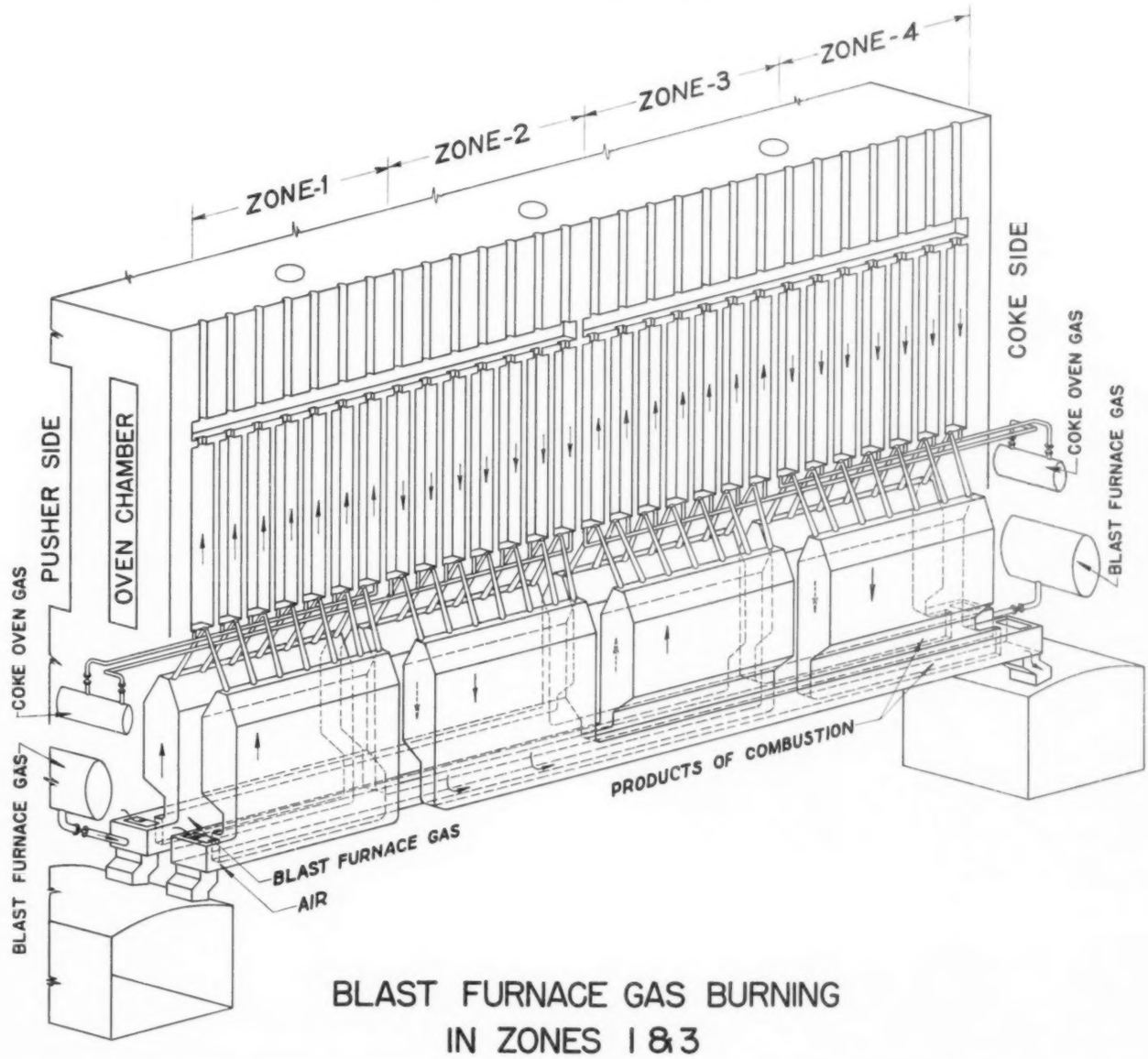
FIGURE 4—View showing start of excavation for coke ovens, showing ground conditions which necessitated the use of piles.

When producing foundry coke, the run of oven coke is delivered to screen No. 1, a double deck vibrating screen. The coke across the top screen having a size of 4 in. and over is foundry coke and is delivered to cars under the screening station by means of a picking table and boom loading conveyor.

The coke through the top 4 in. screen and over the bottom 2½ in. screen is run through a crusher and reduced to minus 2½ in. for domestic coke which is then conveyed to No. 3 screen. This is a double deck vibrating screen over which the egg and nut coke is separated and loaded into cars under the station or conveyed to the domestic bins. The breeze can be either loaded into cars or conveyed by belts direct to the breeze bunkers in the boiler house. For the production of furnace coke the sizes over 4 in. are passed through the crusher and reduced to 4 in. and under. The coke then passes over No. 2 screen which is a single deck vibrator with 1½ in. screen cloth. The coke passing over the screen is conveyed to the high-line trestle and loaded into railroad cars by means of a boom conveyor. This high-line is connected to the blast furnace trestle and the cars, after being weighed, are transported to the blast furnace bins by means of a fireless steam locomotive.

The coke through No. 2 screen, i.e. under 1½ in. is taken to the domestic screens previously mentioned and screened to domestic sizes. At present we are classifying this into three grades. Nut coke 1½ x 1 in., pea

FIGURE 5—Sectional view of oven, showing flue arrangement and flow diagram of gases.



coke 1 x $\frac{5}{8}$ in. and breeze coke under $\frac{5}{8}$ in. The nut coke is loaded into cars and used in the blast furnace, the pea coke is sold to domestic trade and the breeze used as fuel in the boiler house.

All coke and coal handling equipment including by-pass gates are electrically interlocked so that if any unit should stop for any cause, all the conveyors in the system behind it stop so as to prevent the pile-up of coal or coke.

An inter-communication loud speaker telephone system was installed at all emergency points in the coal and coke handling departments. This system has proven satisfactory and gives all operators immediate contact with the master operator and other operators throughout the department.

The gas from the ovens ascends up short brick-lined stand pipes through a liquor seal to the collector main on the pusher side of the oven. The liquor seal is effected by a Corliss type plug valve. The collector main is built in three sections with equalizer connections between sections. Each battery has three cross-over mains, one for each collector main section, each provided with a butterfly valve operated by an oil controlled regulator actuated by the pressure in the collecting main. The cross-over mains connect to a common main which conducts the gas to the by-product plant.

The by-product building and equipment were designed to fit into a limited ground area, making it necessary to depart from the usual arrangement for such equipment. The pumps, controls and instruments for all the operations are located in the west end of the building with the three exhausters and their auxiliaries located in the east end.

The gas cooling, scrubbing and purifying apparatus are located along the north side of the by-product building. The primary and secondary coolers are elevated on structural supports in a manner permitting the location of certain running tanks and decanters underneath at yard elevation. There is one floor elevation above these tanks on which are located the floor stand controls for all gas valves on the apparatus. Suitable stairways and landings are provided for reaching the tops of all cooling and scrubbing towers.

The distillation equipment is located outside on an elevated shelf along the south wall of the by-product pump room. There are provided stairs and landings suitable for servicing all of the distillation equipment. All operating controls for the distillation units, such as water, steam, reflux, gauges, recording instruments, etc., are located inside the by-product building on the main operating floor.

All heat exchange units, such as coolers, condensers and preheaters, are of the shell-and-tube-type. These units are located over the pump house, the roof of which forms one of the two operating floor levels for these units. Most of the units are suspended in a vertical position from a structural framework with the second operating level formed on this support. A hand operated gantry crane is provided over these units for the removal of tube bundles. A second gantry crane is provided for servicing the exhauster equipment.

All pump units are located in the by-product building on the main operating floor. It was found by grouping the equipment in the manner described that it not only saved valuable ground area but simplified considerably the arrangement of an otherwise complicated system of small and large piping. The conveniences to be had from such an arrangement have proved both beneficial and economical in actual operations.

At the by-product plant the flushing liquor together with tar and liquor condensed by the cooling of the gas is drained from the main into the flushing liquor decanter while the gas passes on to the primary cooler.

In the flushing liquor decanter the tar is separated from the liquor by the difference in specific gravity. The tar flows continuously by gravity to two tar dehydrators where the tar is treated by steam coils driving off the water and carbolic oil as vapor. The dry tar is pumped continuously, by means of steam driven float controlled reciprocating pumps, to two 300,000 gallon tar storage tanks from which the tar is loaded to tank cars at the loading station.

The vapor from the tar dehydrators passes through a shell-and tube-type cooler, using plant service water for cooling, condensing the water and carbolic oil which passes through a decanter, separating the oil and water. The water passes to the contaminated water catch basin and the carbolic oil to a storage tank from which it is pumped to railroad cars at the carbolic oil loading station.

The flushing liquor decanted or separated in the flushing liquor decanter flows by gravity to the flushing liquor circulation tank from which the liquor is pumped to the collector main sprays by two 3500 gpm. centrifu-

FIGURE 6—The ovens are provided with self-sealing doors seating on a removable door frame.

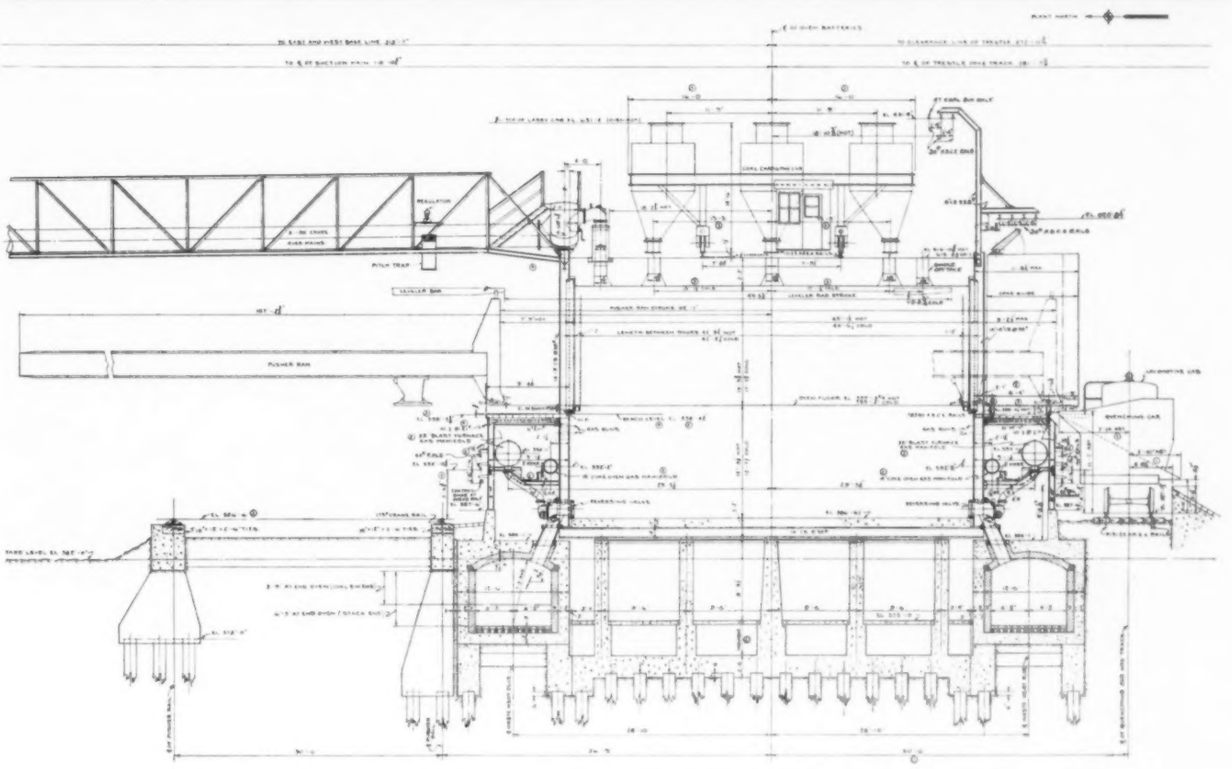


FIGURE 7—General cross-section through coke oven battery, showing pusher ram and quenching car positions.

gal pumps, one electrical and one steam driven. One pump only is operated and the other acts as a spare.

Surplus liquor is drawn from the pump discharge line by a float controlled valve. The surplus liquor passes through two shell and tube-type coolers to two 160,000 gallon weak liquor storage tanks.

The raw gas from the ovens passes through the primary and secondary coolers arranged in two parallel groups, each containing one primary and one secondary cooler. The coolers are of hurdle type where the gas passes up through wood grids sprayed with ammonia liquor through sprays in the top of the cooler tower.

The liquor spray system has two 2400 gpm. centrifugal pumps, one electrical and one steam, of which one is a spare. The secondary cooler system utilizes one 1000 gpm. centrifugal pump connected so that the spare primary pump also acts as a spare for the secondary coolers. The ammonia liquor from the base of the cool-

FIGURE 8—View showing coke being pushed into quenching car. Segmented contact rails above the door machine provide contacts for the interlock system.

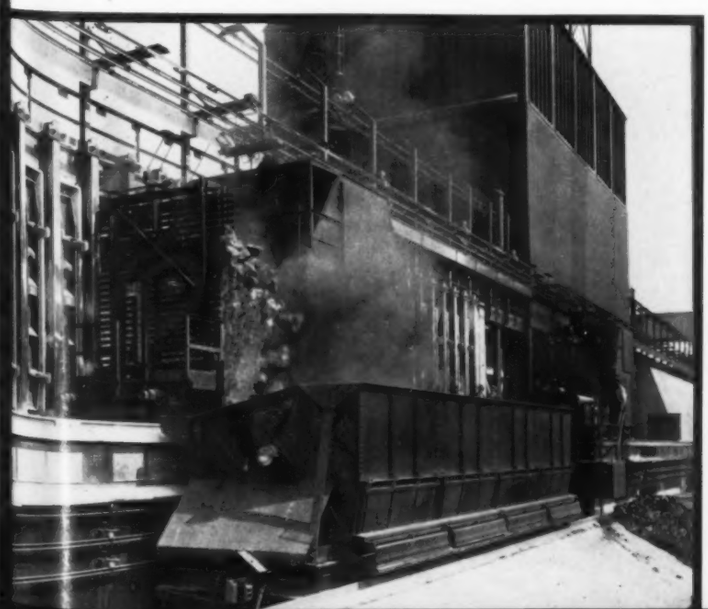


FIGURE 9—This view shows the coke side of No. 2 battery, with the coke wharf in the foreground and the 1,500,000 cu. ft. blast furnace gas holder in the background.

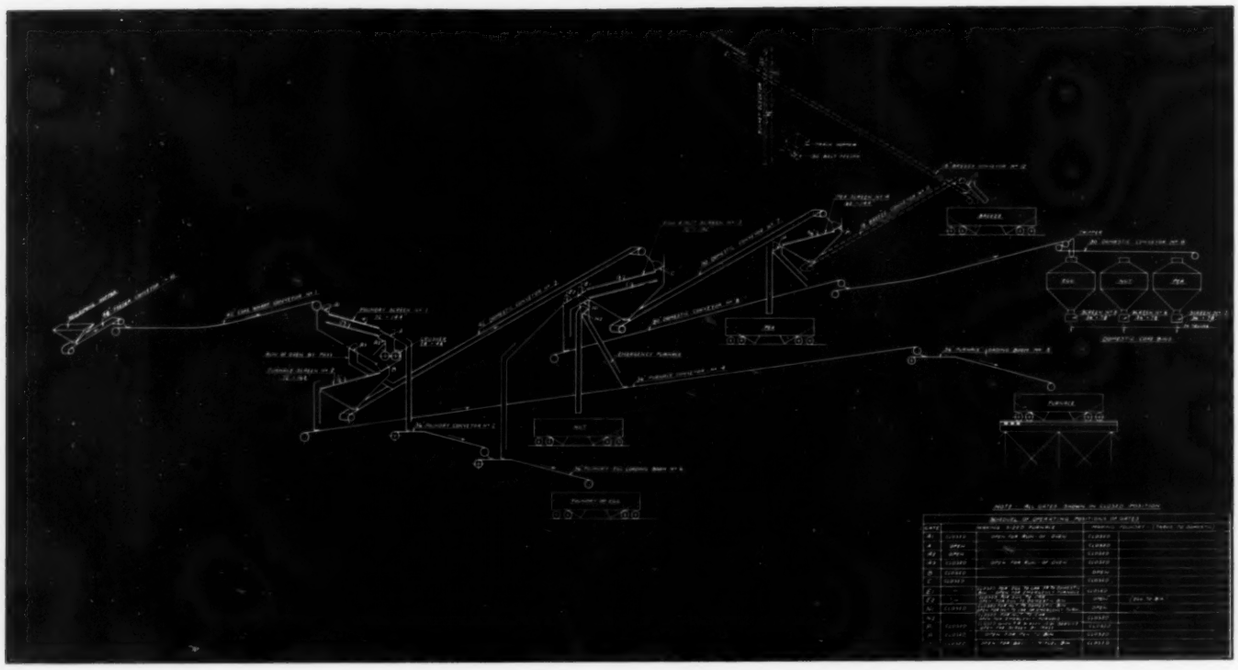
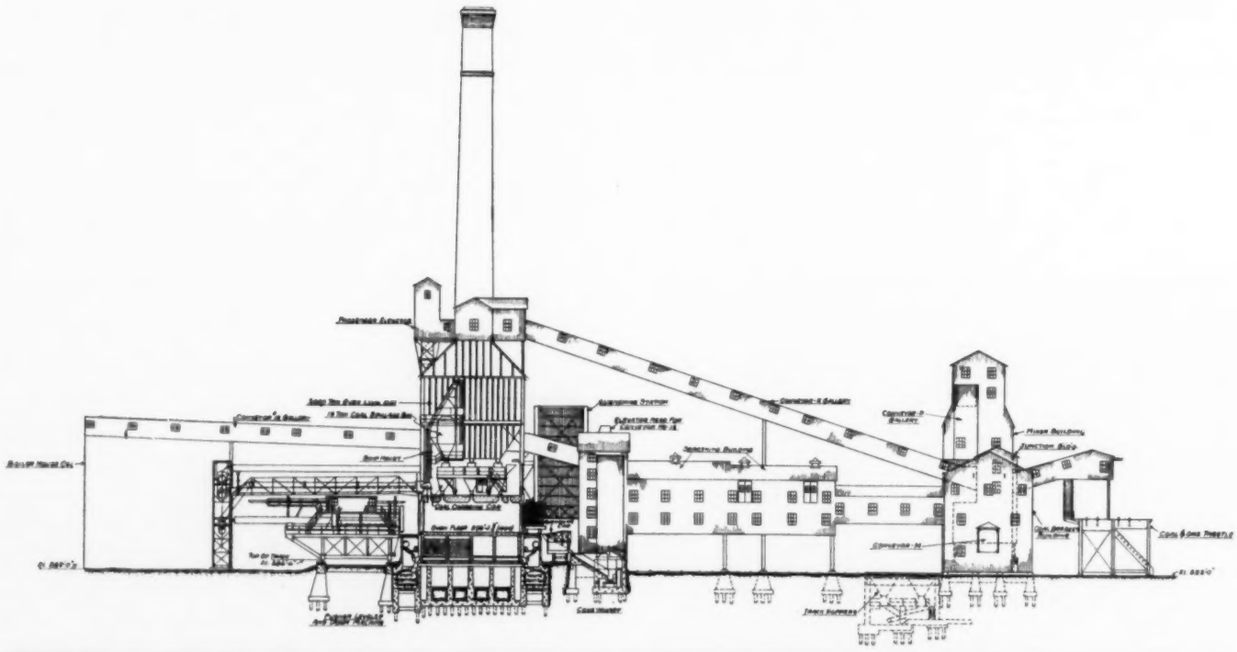


FIGURE 10—Schematic diagram of coke handling system. The screening station has a capacity of 175 tons per hour.

ing towers is pumped through shell-and tube-type coolers to the sprays at the top of the towers. The surplus liquor flows by gravity to the flushing liquor decanter.

After the secondary coolers, the gas is passed through exhausters, two operating and one spare, steam turbine driven with 400 lb.–700 degree steam exhausting at a back pressure of 150 lb. Each unit has a capacity of 15,500 cu. ft. per min. The 150 lb. steam is desuper-

FIGURE 11—General arrangement showing elevation of oven battery, and coal and coke handling systems.

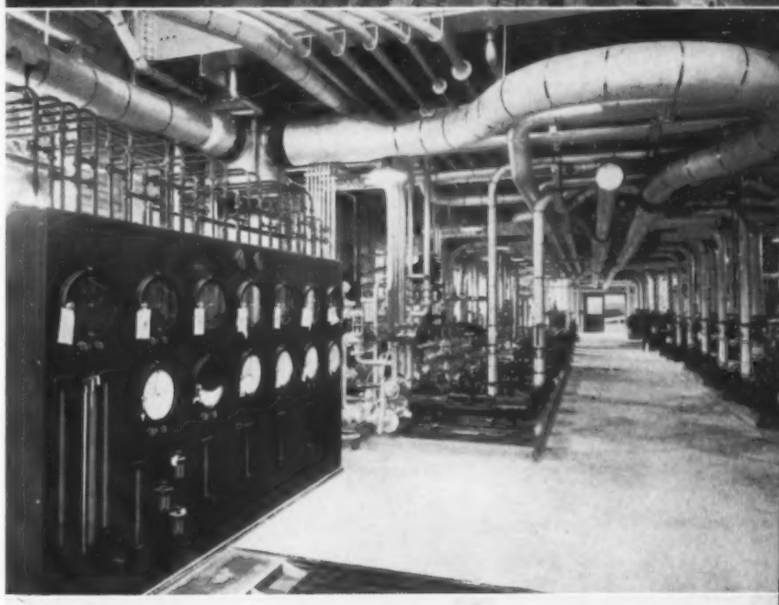


heated and used in the by-product and benzol plants, for operating pumps and equipment.

On the discharge side of the exhausters the gas passes through the tar precipitators, sulphur scrubbers, light oil scrubbers and to the surplus coke oven gas main. Three electric tar precipitators connected in parallel were installed with a complete spare set of electrical equipment.

The sulphur scrubbers, two in number and operating in parallel, are also of the hurdle type with the gas passing up through wood grids sprayed with ammonia liquor. The liquor from the base of the scrubber is pumped to the top of the sulphur eliminating column where the liquor is subjected to exhaust steam as it flows over a series of bubble trays driving off the sulphur in the form of hydrogen sulphide. The liquor is then pumped from the base of the sulphur eliminator through shell-and-tube-type coolers to the sprays at the top of the sulphur scrubbers. The surplus liquor overflows from the base of the scrubbers to the flushing liquor decanter or is pumped to the weak liquor storage tanks.

Two primary and two secondary light oil scrubbers were installed. They form two parallel units each consisting of one primary and one secondary scrubber in series. These units are of the hurdle type with the gas passing up through wood grids sprayed with wash oil which absorbs the light oil from the gas.



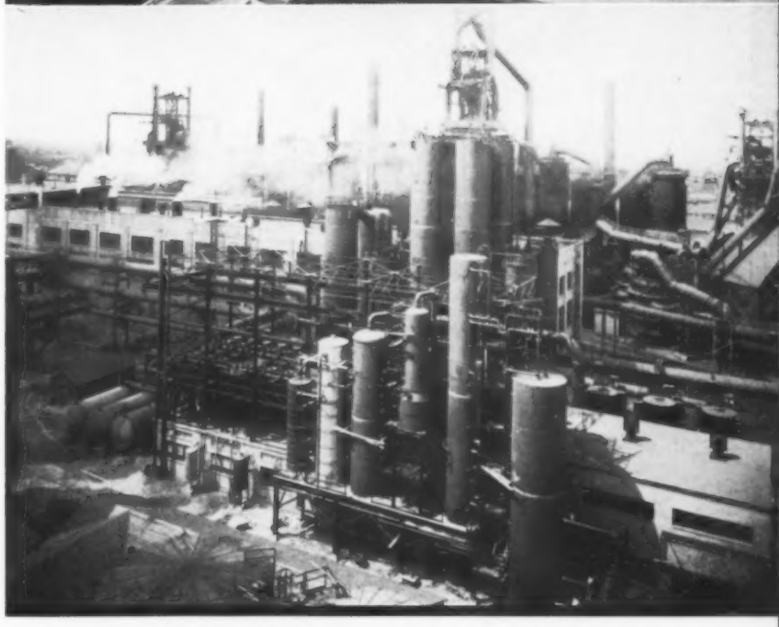


FIGURE 12—General view showing No. 2 ore yard to the left, No. 2 quenching station to the right, and coal and coke handling buildings, center.

FIGURE 13—Interior view of by-product pump room, with instrument panel at left. Exhausters are located in opposite end of this building.

FIGURE 14—General view of by-product plant, showing light oil stills and ammonia still in foreground, coolers and scrubbers in background.

The wash oil enters the sprays at the top of the secondary scrubbers and passes through the grids to the base of the scrubber. From the base of the secondary scrubber the oil is pumped to the sprays at the top of the primary scrubber passing through the grids to the base. From the bottom of the primary scrubber the oil passes through shell-and tube-type vapor to oil heat exchangers, oil to oil heat exchangers, preheaters and to the top of the stripping still. Entrainment separators are provided on the outlet of the sulphur scrubbers and secondary light oil scrubbers.

In the stripping still the benzolized wash oil flows over a series of bubble trays and is subjected to exhaust steam driving off the light oil as vapor and the debenzolized wash oil collects in the base of the stripping still.

The wash oil from the base of the still is pumped through the shell-and tube-type oil to oil heat exchangers to the wash oil decanter, where the water is decanted. The water flows to the muck tank and the clean wash oil to the wash oil circulation tank from which it is recirculated.

The light oil vapors from the top of the stripping still pass through the vapor to oil heat exchangers to the

base of the crude residue separating column where the vapors pass up through a series of bubble trays flushed with cool light oil supplied at the top of the column. The cooling of the light oil vapors condenses the water and residue which is decanted in the base of the residue column. The water flows to the muck tank and then to the contaminated water catch basin and the residue to the residue stripper where the residue flows over a series of bubble trays and is subjected to direct and indirect steam driving off the light vapors to be returned to the residue separating column and final residue is drained to the crude heavy solvent naphtha storage tank at the benzol plant.

The light oil vapors leaving the top of the residue separating column pass through shell-and tube-type condensers and after-coolers, thence to the decanter where the water is separated and the oil drained by gravity to the crude light oil storage tanks at the benzol refining plant.

Due to unsatisfactory market conditions for ammonia sulphate, no equipment has been installed in this plant for its recovery. The weak ammonia liquor is being sold to a local ammonia concentrating plant.

The many engineering features of the new coke and blast furnace plants of Great Lakes Steel Corporation attracted a representative cross-section of the industry to the inspection trip of the Association of Iron and Steel Engineers, held April 19, 1939. Shown at top are H. V. Lauer and L. F. Zanini; A. R. Schulze and F. E. Kling, center; bottom, A. G. McKee, A. E. Leek, and C. C. Wales.

Approximately half of the ammonia in the gas is recovered in this form.

Provisions, however, have been made to dephenolize and remove the free ammonia from the ammonia liquor to prevent stream polution in case, due to market conditions, the liquor must be drained to the river.

In the phenol plant the weak liquor is mixed with light oil and thoroughly mixed by a centrifugal pump during which the light oil absorbs the phenols. The weak liquor light oil mixture is pumped to a decanter where the phenolized light oil and the liquor are separated. This process is repeated and the now dephenolized ammonia liquor flows to a pump tank from which a centrifugal pump discharges the liquor to the top of the ammonia still where by using direct steam passing up through the liquor which flows down over a series of trays, the free ammonia is driven off as a vapor and is returned to coke oven gas main. The ammonia liquor now free of phenols and free ammonia flows to the sewer.

The phenolized light oil is passed through a sulphur scrubber where the oil entering through sprays passes up through a bath of water removing the sulphur com-

pounds. The water is drained to the contaminated water basin and the light oil to the light oil treatment tower where the light oil entering through sprays bubbles up through a caustic solution which absorbs the phenol forming caustic phenolate or carbolate.

The dephenolized light oil is drained to a settling tank and is recirculated through the phenol removal system. The carbolate is drained to the carbolate cooker, heated with steam coils, driving off the water and the residue or carbolate is drained to the storage tank from which it is pumped to tank cars at the loading station.

The benzol plant consists of two batch process acid washers and a continuous process for refining motor benzol, pure benzol, pure toluol and solvent naphtha from the crude light oil.

From the crude light oil storage tanks the light oil is pumped to the acid washers where the oil is first washed with sulphuric acid and then neutralized with caustic. Acid and caustic are transferred from the storage tanks to the feed tanks over the washer by means of blow tanks, the liquids being transmitted by air presure. The residue or sludge is allowed to settle to the bottom of the washers, then drained to the sludge blow tank. The sludge is loaded into ladle cars and dumped on the waste pile and the washed light oil is drained to storage tanks.

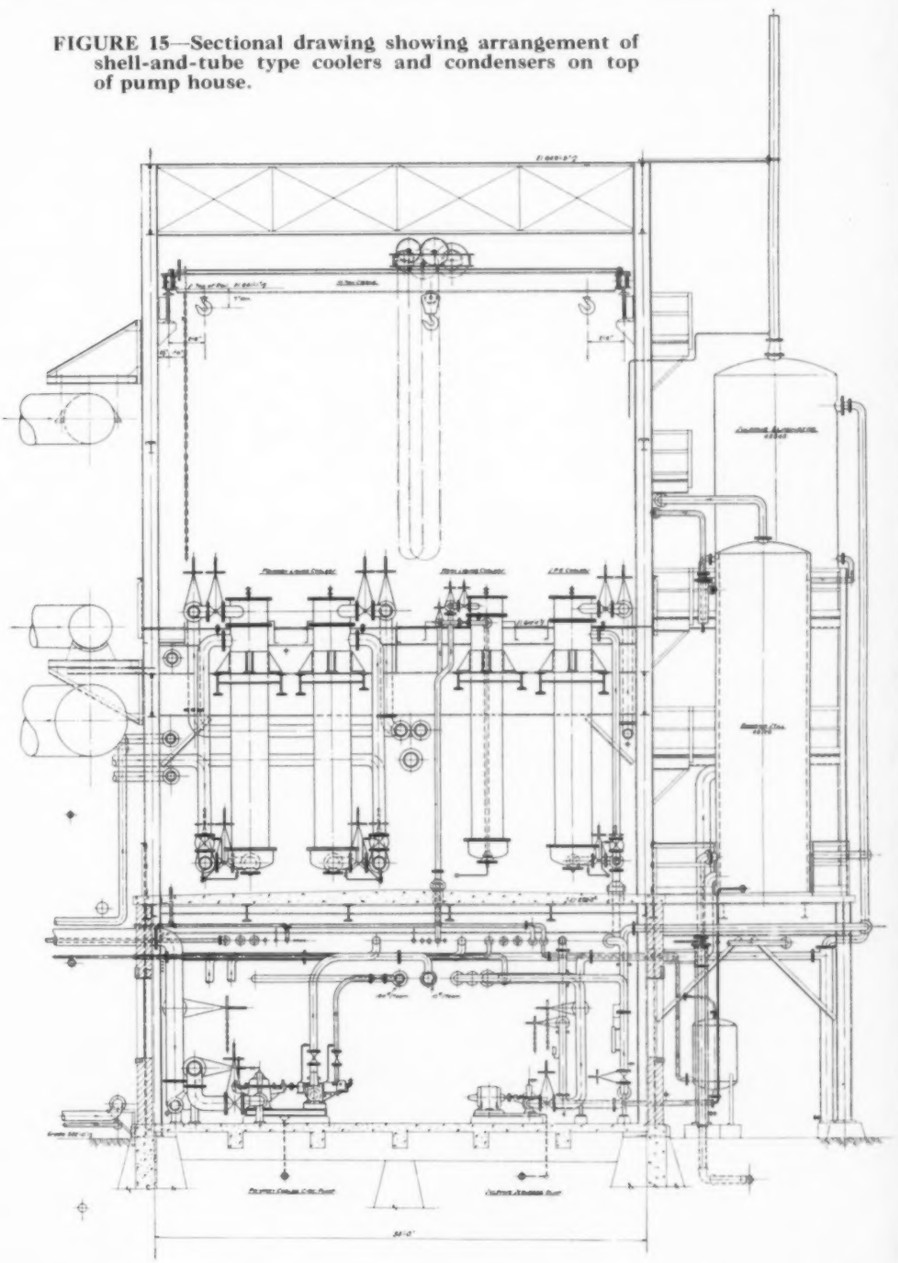
The washed light oil is then pumped to the top of the pure still residue separating column where the oil flows down over a series of bubble trays and direct steam passes up through the oil. The heavy residue settles to the bottom of the column from which it is run to settling tanks where the water and residue are separated. The water is drained to the contaminated water catch basin and the residue to a storage tank.

The vapors from the top of the residue column are passed through shell-and-tube-type condensers and coolers to a decanter where the product and water are separated. The water is drained to the contaminated water catch basin while the product is drained to a pump tank from which a centrifugal pump, float controlled, pumps part of the product to the top of the residue separating column to be used as reflux for temperature control and the remainder to the product receiver tanks. After testing the product, if found satisfactory, it is run by gravity to a storage tank.

From this tank the oil is passed successfully and continuously through three fractionating columns with the resulting products; motor benzol, pure benzol, pure toluol and solvent naphtha. Each column consists of a series of bubble trays and a steam coil heated boiler still connected to the bottom of the column. By controlling the temperature, the product desired is driven off as vapor and the remainder collects in the boiler still to be pumped to the next column.

Thus the light oil free from pure still residue is pumped to the top of the motor benzol column and passes down over a series of bubble trays while the vapors from the boiler-still connected to the base of the column pass up through the oil so that all product having a boiling point below that of pure benzol, i.e. motor benzol is driven off as vapor while the higher boiling point product remains in the boiler still. The vapors off the top of the column pass through shell-

FIGURE 15—Sectional drawing showing arrangement of shell-and-tube type coolers and condensers on top of pump house.



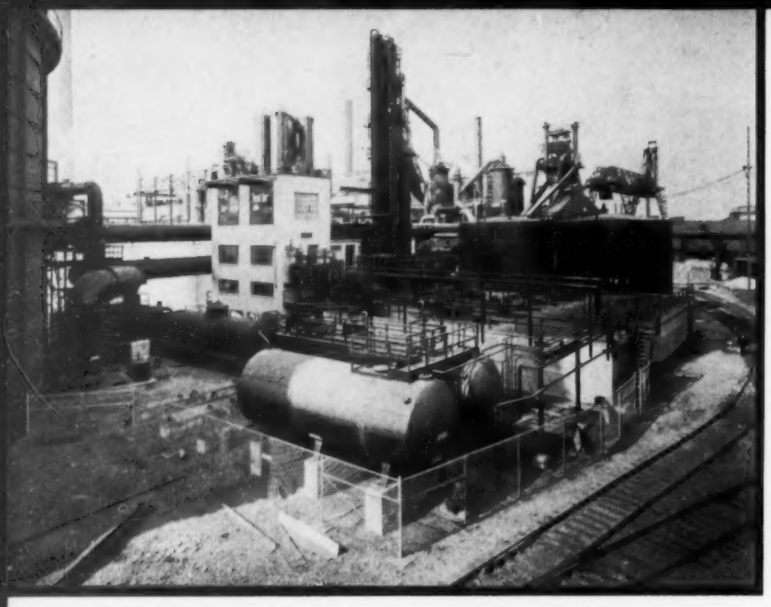


FIGURE 17—General view of benzol plant, showing fractionating columns, and storage and running tanks.

and-tube-type condensers and coolers, then to a decanter where the water is separated from the motor benzol. The motor benzol flows to a pump tank from which part of the product is recirculated as reflux through the motor benzol fractionating column while the remainder is pumped to the motor benzol storage tank.

The product remaining in the motor benzol boiler still having a boiling point of benzol and higher is pumped to the top of the pure benzol fraction column where by the same method product meeting benzol specification is driven off as vapor to be condensed as pure benzol.

The unvaporized product, having boiling points above pure benzol are pumped from the pure benzol boiler still over the bubble trays in the pure toluol column vaporizing the product meeting toluol specifications to be condensed as pure toluol. The vapors from the base of the toluol column having a boiling point just above that of pure toluol are condensed as solvent naphtha. All the higher boiling point products remaining in the boiler still are cooled and drained to the motor benzol storage tank.

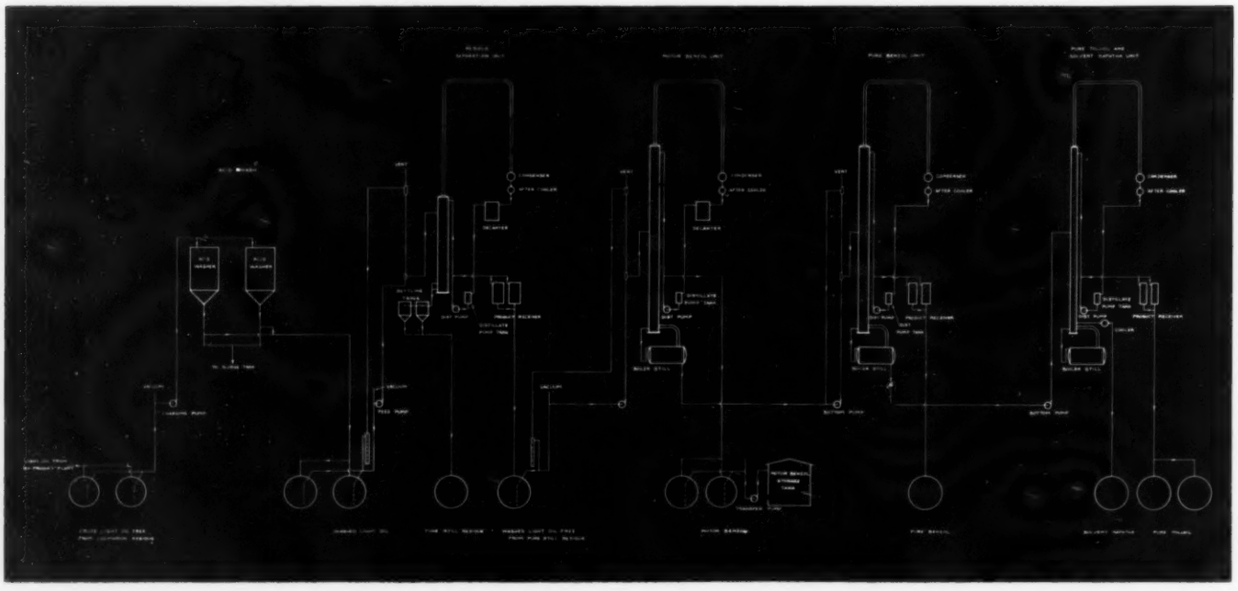
In addition to the buried storage tanks of which there are 14, having a capacity of 17,000 gal. each, a 160,000 gal. storage tank has been installed to be used either for storing motor benzol or pure benzol.

All benzol plant products are pumped to a tank car loading station where the products are loaded for rail shipment. A truck loading station also was installed, thus providing for local shipments.

Throughout the by-product and benzol plant, considerable thought was given to fire protection. Due to the fact that pipe trenches are extremely hazardous, the plant was constructed with only one trench in this area in which are laid ammonia liquor lines. All tanks storing inflammable liquids are buried with the exception of the 160,000 gal. tank which is provided with a steel dike. These tanks are also equipped with approved type flame arrestors. All equipment and pipe lines are well grounded; a sprinkler system is installed in the benzol buildings and there are self-closing fireproof doors between the agitator building and the adjoining benzol building. All electrical equipment in this area is of the approved explosion proof type. Foam generators, foam hand extinguishers and CO_2 extinguishers are located throughout this department for fire fighting.

As mentioned before, the ovens are arranged for either blast furnace or coke oven gas underfiring. Normally the coke ovens will be fired with blast furnace gas, reserving the coke oven gas for use at the steel plant. The blast furnace gas from the furnace washers pass through a 352 tube two-compartment electrical precipitator where the gas is cleaned to .01 grain per

FIGURE 16—Flow diagram of continuous benzol refining equipment.



cu. ft. To insure a constant supply of blast furnace gas for the coke ovens, a 1,500,000 cu. ft. dry seal gas holder was installed. This holder also supplies gas to the booster and mixer station where the coke oven and blast furnace gas are mixed to form a 375 Btu. gas for use at the steel plant, located three miles west of the coke plant.

Due to lack of space, the gas mixing and booster station had to be isolated from the by-product building. This station at present contains three electrically driven turbo boosters, the motors of which are 1000 hp., 3-phase, 4600 volts. A room adjacent to the booster station and sealed from all possibilities of gas infiltration, houses the electrical control, cubicles and recording calorimeters.

The gases are here mixed by means of automatic equipment and pumped through a 42 in. main to the steel plant at Ecorse. The gas distribution system at Zug Island is very flexible and controlled entirely by means of automatic regulators actuated by gas pressure. With this arrangement, a small fuel gas holder is not necessary.

As noted in the description of the by-product equipment, a number of the pumps are operated either electrically or by means of steam turbines and that the 150 lb. steam requirements are furnished by the exhaust steam from the exhauster engines. The steam turbine

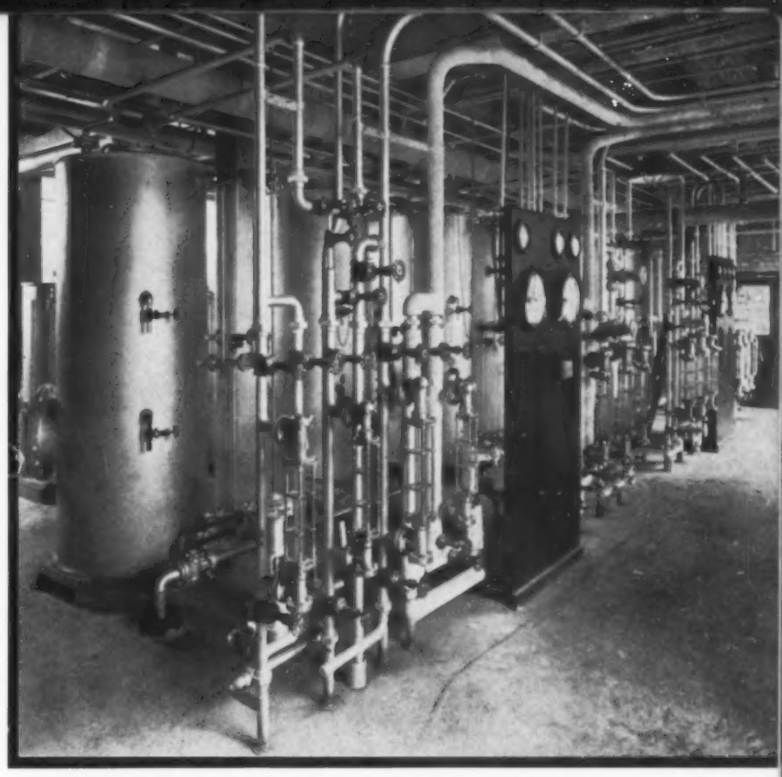
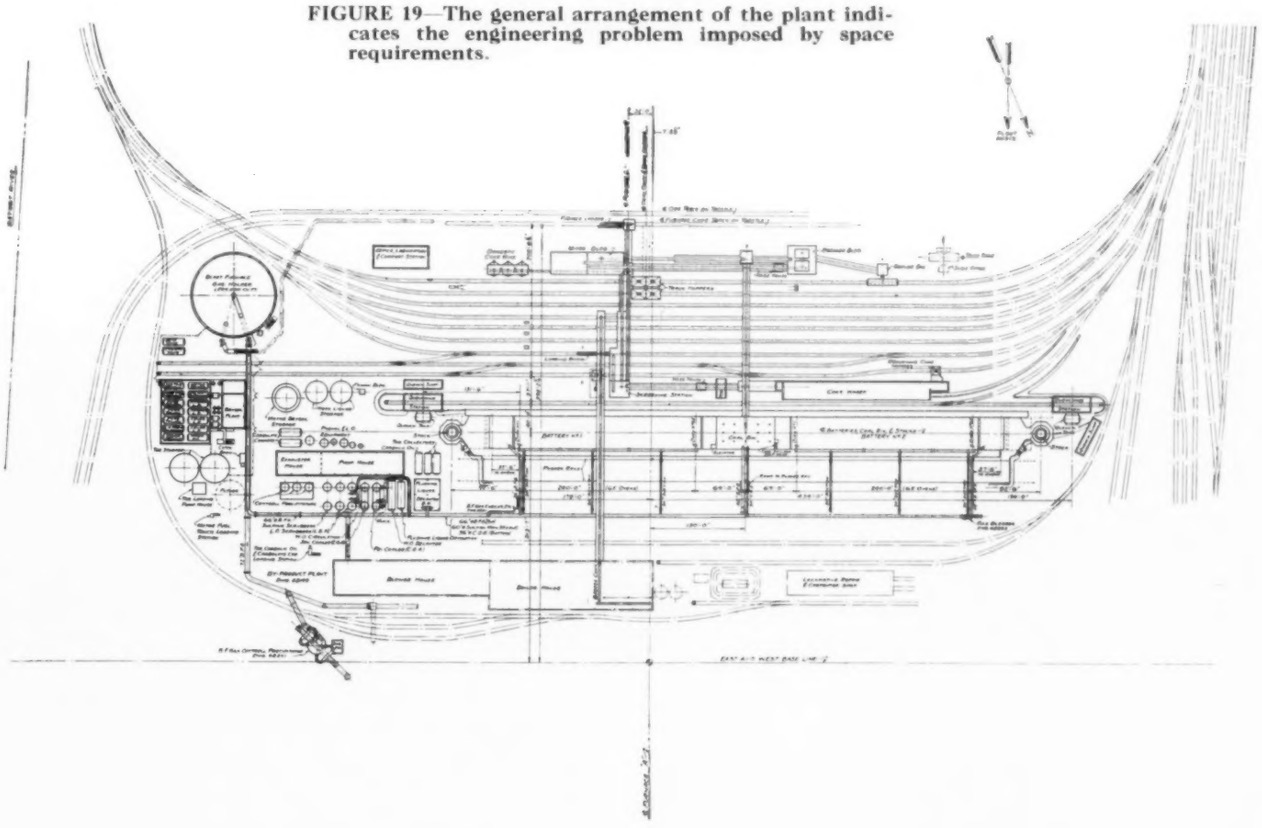


FIGURE 18—Operating floor of benzol plant, showing receivers for the benzol products.

FIGURE 19—The general arrangement of the plant indicates the engineering problem imposed by space requirements.



driven pumps exhaust into an 8 lb. line and this steam is used in the processing equipment.

By means of interchanging the type of drive on the pumps, we are able to maintain a balance on our steam and power loads.

The following tabulations show the coke and by-product yield, coal used and steam, water, gas and electric power consumption from actual meter readings

Average analysis of mixed coal charged into ovens:

Volatile matter	32.5 %
Fixed carbon	62.1 %
Ash	5.4 %
Sulphur	.78%
Moisture	4.00%

Average analysis of furnace coke:

Volatile matter	0.8 %
Fixed carbon	92.7 %
Ash	6.5 %
Sulphur	.61%
Moisture	3.00%

Yields per ton of natural coal:

Furnace coke	65.0 %
Nut coke	3.7 %
Pea coke	1.5 %
Coke breeze	3.9 %
Total	74.1 %
Total gas yield	10,200 cu. ft.
Tar yield	8.85 gals.
Ammonia yield	3 lb.
Carbolic oil yield	.24 gals.
Light oil yield	3.25 gals.
Motor fuel	1.37 gals.
Pure benzol	.92 gals.
Pure toluol	.50 gals.
Solvent naphtha	.14 gals.
Total gals. of pure products	2.95 gals.

Consumption:

Bhp. steam per ton natural coal	8.82
Power kwh. per ton natural coal	10.00
Water per ton natural coal	2000 gals.

J. A. Clauss was among those participating in the technical meeting held after the inspection trip.

DISCUSSION

PRESENTED BY

B. M. STUBBLEFIELD, Superintendent, Coke Ovens and Blast Furnace, Youngstown Sheet and Tube Company, Youngstown, Ohio.

H. V. LAUER, Assistant Superintendent, Coke Plant, Carnegie-Illinois Steel Corporation, Gary, Indiana.

B. M. STUBBLEFIELD: I have nothing to say about the blast furnace plant. It is a good job throughout. It has required skillful engineering, to say the least, to place so large a furnace securely on the limited ground space offered, limited both as to size and load bearing qualities.

The foundation work under the ovens also represents a rather remarkable piece of engineering. Certainly, if there is anything in foundations, these batteries at Great Lakes should be here a long while.

I was much impressed by the means provided for handling and stocking coal. The usual method has of course been by means of bridges, which to say the least, are unwieldy and cost a lot of money to erect and maintain.

In this case a comparatively simple layout of a bin and conveyor belts provides an unloading capacity of 1,200 tons per hour and a stocking capacity of 600 tons per hour. This is indeed worthy of note. Then, to think that you can go in with a single bucket-type crane and recover 450 tons per hour from storage is almost beyond belief.

I am of the opinion that the construction of this type of coal storage yard is a step in the right direction.

There is one thing in the coal preparation plant that I would question, although it is subject to discussion, pro and con. I have never thought it good practice to put Pocohantas coal, that is the slack, through a hammer mill. In this particular layout there is some gain, as breaker sized coal is stored in three of the four mixer bins, which certainly lends to the cleaning of the bins. Furthermore, it must be admitted that the new type hammer mills do not produce the extremely fine coal that the old type mills will. Therefore, in this particular plant it is entirely possible that the advantage gained in bin cleaning and the mixing given the coal

in the hammer mill more than offsets the effect of fine coal produced in the mill.

In the matter of charging cars I believe that these large ovens could be charged more uniformly and in less time with a car carrying four hoppers than they can with the three-hopper car.

This is particularly true when the coal is wet, as it is apt to be coming from storage.

The by-product and benzol recovery equipment certainly does not resemble that built some ten to fifteen years ago, it being more compact and more nearly continuous in the operating cycle.

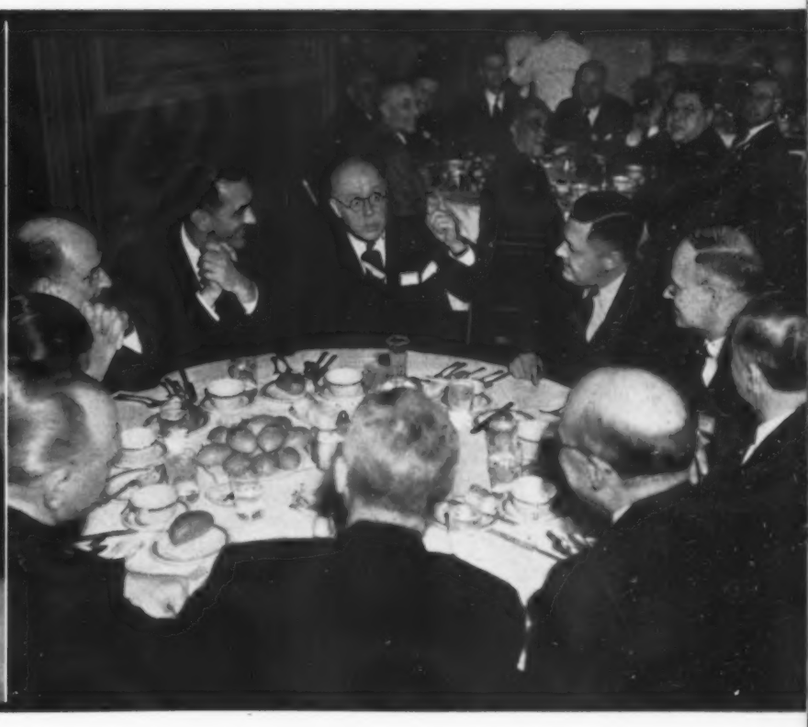
I notice that practically all cooling is done in so-called "shell-and-tube coolers". This type of cooler is of course efficient, but water conditions must be right, otherwise cleaning and maintenance costs are apt to be high.

I believe this covers the points that I wish to discuss. I trust nothing I have said will be taken as criticism, for as I said at the outset these two plants represent a lot of planning and skillful engineering, from which I have no desire to detract.

H. V. LAUER: I would like to express my appreciation for the opportunity of seeing the Great Lakes Steel blast furnaces and coke plant. It is a well built plant and a marvelous job of engineering. One of the things that impressed me in walking about this afternoon was the fact that they have a benzol plant to handle light oil produced from 3300 tons of coal per day which is about one-third the size of a plant anyone would have built ten years ago to do the same job; and in addition to that, doing a job that we would never dream of doing ten years ago as to quality of product, recovery, and so forth.

The self sealing doors looked very good, and the whole plant in general impressed me very much. In fact, when I saw the housekeeping in such good condition, it impressed me that the plant must be well managed.

Above are W. R. Trognitz, B. E. Pheneger and W. R. Pendry, shown as they went through the plant. A dinner was held preceding the technical session. At left, below, are C. V. McIntyre, David Thomson and E. J. McCleary. At lower right, H. B. Pearson, W. H. Pavitt, H. V. Lauer, E. J. Crossen, and others listen as Louis Wilputte holds forth.



Construction of the New 1000 ton BLAST FURNACE at Great Lakes Steel Corporation

By R. M. HUGHES *and* WM. J. REES

Great Lakes Steel Corp.

ECORSE, MICHIGAN

▲ IN order to describe the construction of our new 1000-ton blast furnace and, if possible, bring out some of its distinctive features, it will probably be in order to first explain the geographical location of the plants of the Great Lakes Steel Corporation in order that those not familiar with these locations can have a better understanding of this paper.

The blast furnace and coke plants are located at a distance of about three miles from the steel plant, the steel plant being in Ecorse and the blast furnaces on Zug Island, which is just outside of the corporate limits of Detroit, Michigan, in River Rouge.

R. M. Hughes, assistant chief engineer, shown addressing the technical meeting at Detroit, April 19, 1939.

The construction of this furnace was but a part of a construction program of considerable magnitude which took place at the same time, both at our steel plant in Ecorse and at the blast furnace plant on Zug Island.

The erection of a new coke plant on Zug Island was also a part of the development program at the blast furnace plant.

In recent years the building of a blast furnace has usually consisted of rebuilding an existing smaller furnace with but limited changes to the hot blast stoves and other auxiliary equipment. In this particular case we were very fortunate in that we had to build a complete new furnace with all its auxiliary equipment.

Previous to building this new furnace, which we call furnace "C", the Great Lakes Steel Corporation had on the Zug Island site two blast furnaces, one at 650 tons daily capacity known as furnace "A" and another of 550 tons daily capacity known as furnace "B". Prior to 1936 the combined tonnage of these two furnaces could supply the needs of the eight open hearth furnaces at Ecorse. Four new open hearths were completed early in 1936, and the necessity for additional hot metal became acute. When it was decided that four additional open hearths were to be built at Ecorse (making a total of 16), it became necessary to build the new blast furnace.

LOCATION AND SIZE OF FURNACE

Space had been provided at the Great Lakes Steel Plant site to build two or three 1000-ton blast furnaces, but to build a new furnace at this site would have necessitated maintaining two complete blast furnace plants with their ore docks, boiler and blower house, and other auxiliary equipment. A thorough study was therefore made of both the Zug Island and Ecorse sites to determine which location was most suitable for the new furnace. At about this same time it was also decided to build the new coke plant; and, since the logical place for this was at the existing blast furnace site, it was decided that the new blast furnace should be located there also.

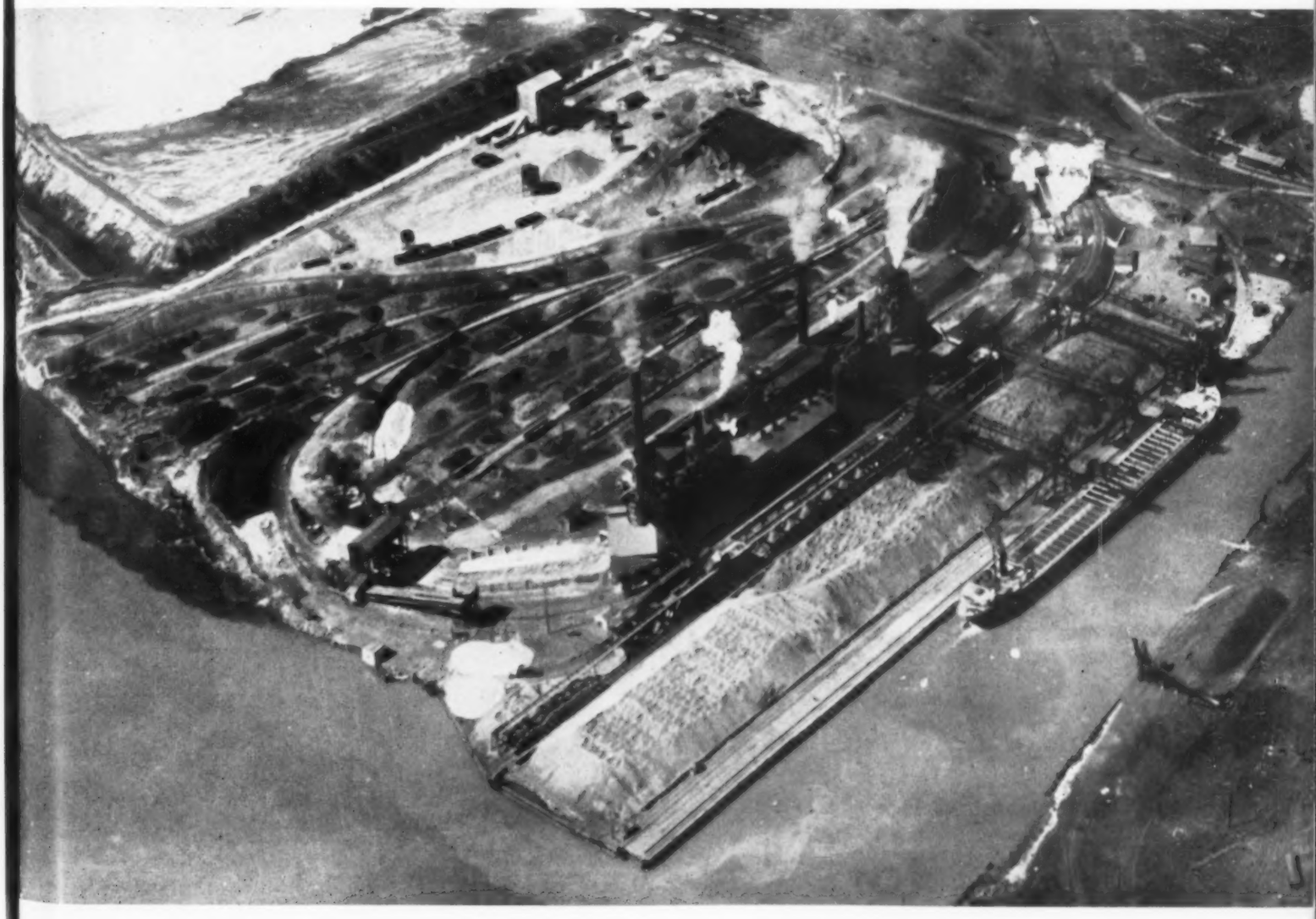
About a year previous to the time a new blast furnace became necessary, it was decided to replace the old steeple-type blowing engines, as well as the old boiler plant, with modern turbo blowers and high-efficiency boilers. I only speak of the replacing of the boiler and blowing engine house because of the part it had in the building and location of the new furnace. The new boiler and blowing engine house was located at a site further from the then existing boiler and engine house; and, when these old structures were removed, sufficient space was provided for the new blast furnace and its auxiliaries.

When the original "A" and "B" furnaces were built, no thought had been given to a third furnace on this site; and evidently no one had considered putting a third furnace between the two existing furnaces.

There is approximately 500 ft. between "A" and "B" furnaces, and the stoves for both furnaces are located between the two furnaces. The old engine house was located between the two sets of stoves; and, when this was removed, there was just enough space for the new "C" furnace with its stoves.

Since the increase of our open hearth plant would require practically double the tonnage of iron previously produced, it was decided to build the furnace

FIGURE 1—Aerial view of the blast furnace plant before the construction of the new blast furnace and coke ovens.



to produce 1000 tons of iron per day for the present and arrange it so that it could be lined to produce a greater tonnage in the future.

RAW MATERIAL STORAGE

Along with the problem of determining the size and location of the furnace, we also had the problem of providing space for raw material storage, as well as providing means to get the raw materials to the furnaces, and to get the hot metal and slag away from it.

The handling and storage of ore was of course our biggest problem, and it was realized at the beginning that the original installation for this would be quite costly.

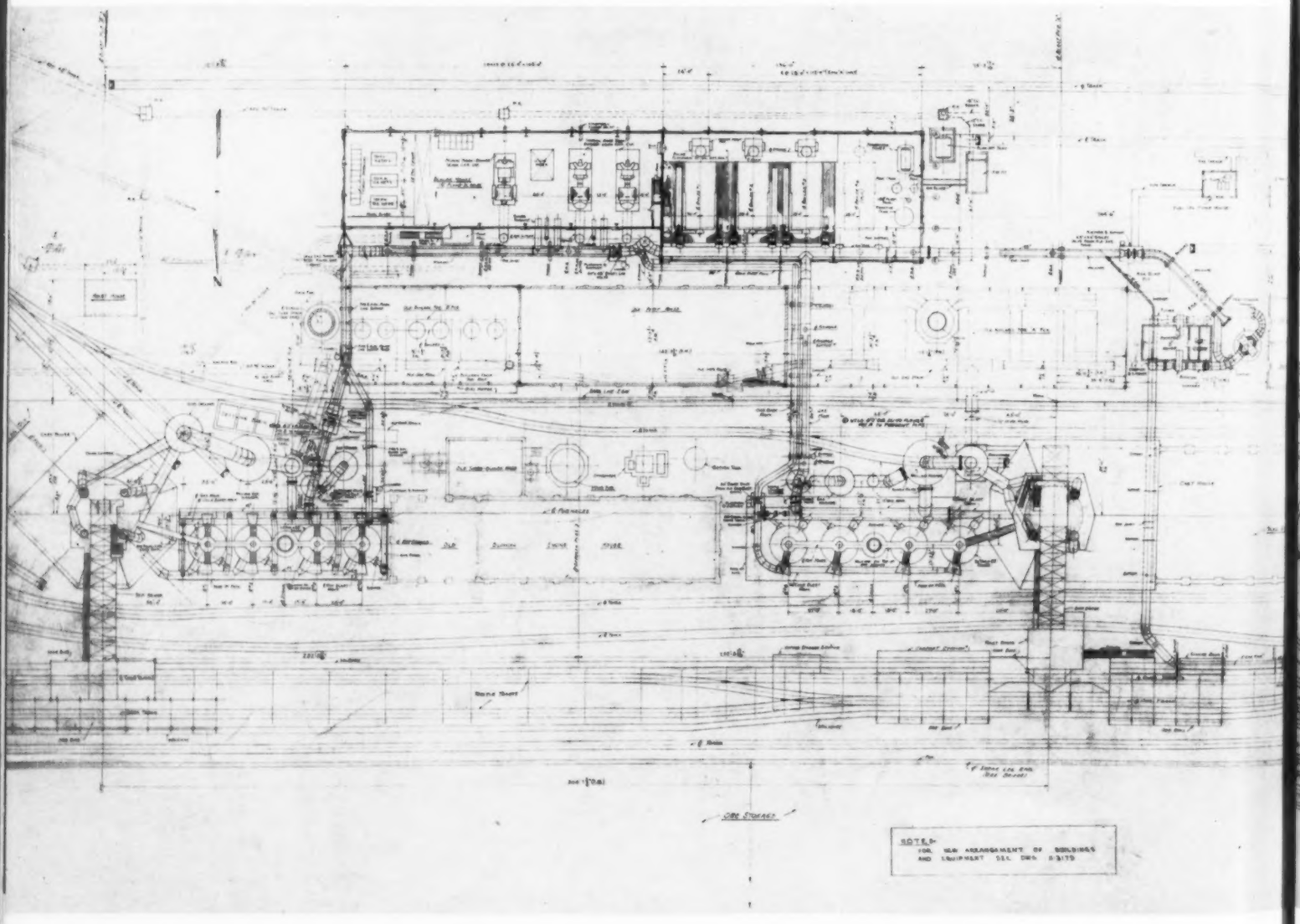
As you know, it is necessary that ore be stored at the plant in the summer for about 165 days of operation during the winter months.

Old "A" and "B" furnaces were located on a line parallel with the Rouge River, and the ore dock for these furnaces was located along the river opposite the furnaces. This old ore storage was approximately 1100 ft. long and 150 ft. wide, and had a capacity of 305,000 tons of ore. It was only possible to extend this dock 120 ft. to the west, which gave 36,000 tons additional storage. This made a total storage capacity of about 341,000 tons, or only about half of the storage space required when the new furnace was put in operation.

Storage space also had to be provided for coal for the ovens, as well as for crushed slag.

The entire storage problem was solved by providing a new storage yard to the south of the coke oven plant and by installing a trestle along the north side of this storage yard, and continuing this trestle along the river front to the old highline. This new trestle is equipped with two tracks at the same level as those on the old highline. In addition to making it possible to move ore

FIGURE 2—Original layout of furnace plant, showing the old engine house between the two existing blast furnaces.



to and from each ore storage, this new trestle is also used for the transportation of coke from the screening station to the coke bins at the furnaces.

This particular layout has worked out very satisfactorily; we transfer the ore and coke, as mentioned, along the trestle without interference with transportation at ground level.

The ore transfer cars are electrically driven and the coke transfer cars are propelled by a fireless locomotive which obtains its steam from the new boiler plant at 400 lb. pressure, suitable stations having been provided along the trestle for charging this locomotive.

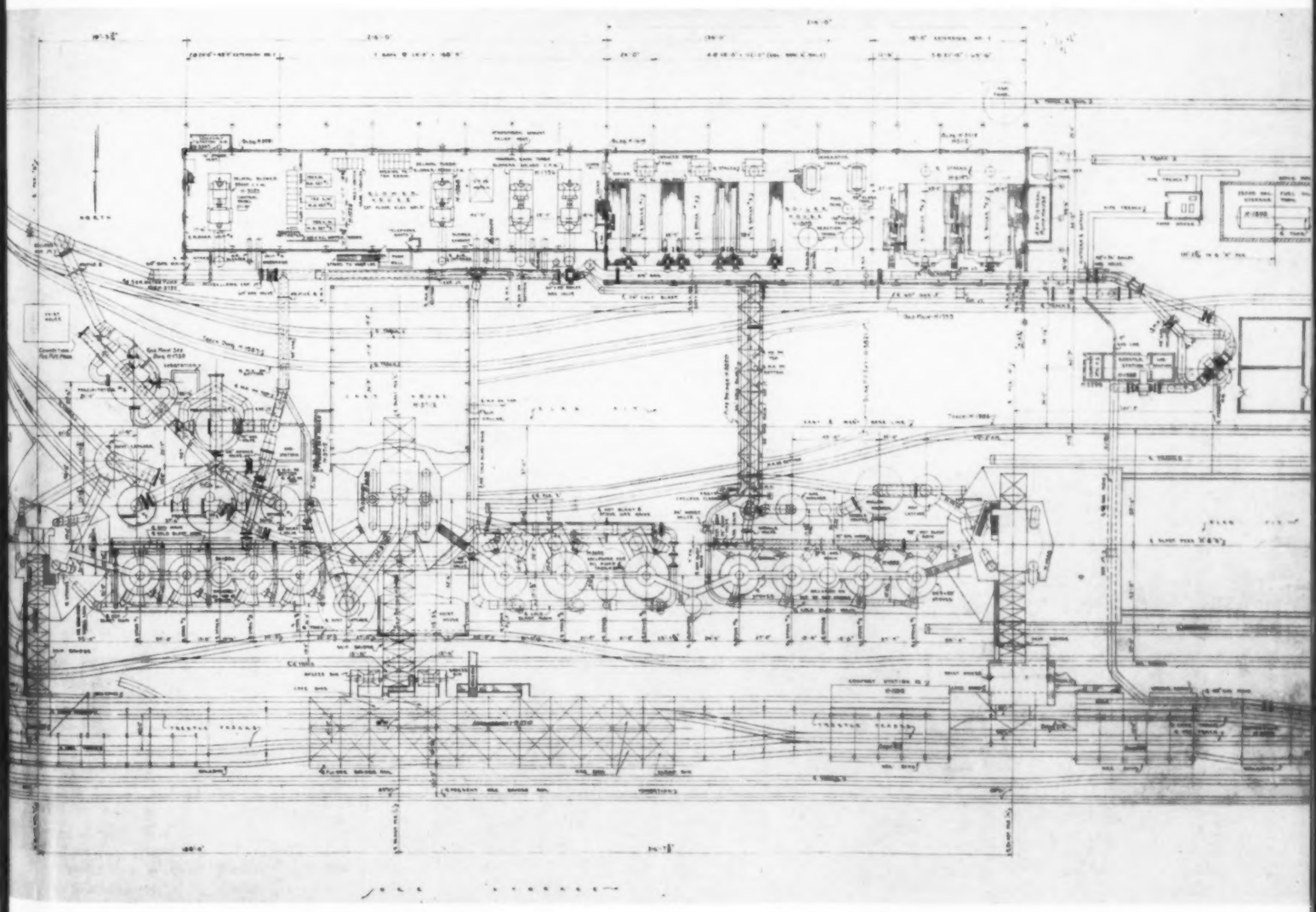
The new 10-ton ore bridges have been installed at the old ore storage yard and two other 10-ton bridges have been installed at the new storage yard. These latter bridges were moved from our Hamburg plant at Buffalo. They were dismantled piece by piece, moved, and re-erected at Detroit. Rusted and worn parts of the bridges were replaced with new material and the bridges put in first-class condition.

LOCATION OF FURNACE AUXILIARIES

Getting back to the furnace auxiliaries, you probably noticed that the space available for this equipment was limited on all sides; and, since we required clean gas for underfiring of the coke ovens, for "C" furnace stoves, and for the mixing of this gas with coke oven gas for use at the steel plant, the arrangement of the gas cleaning equipment due to these physical restrictions developed into quite a problem.

It was necessary to clean the gas from both "B" and "C" furnaces in the space available. Prior to this time we were not equipped at "A" or "B" furnaces to supply gas of the cleanliness required. At "A" furnace we had a small precipitator to clean part of the gas from this furnace for another purpose; but other than that our blast furnaces gas had been passed through dust-catchers and old tower washers. The tower washer at

FIGURE 3—Layout of furnace plant showing the new blast furnace and new enlarged boiler and engine house.



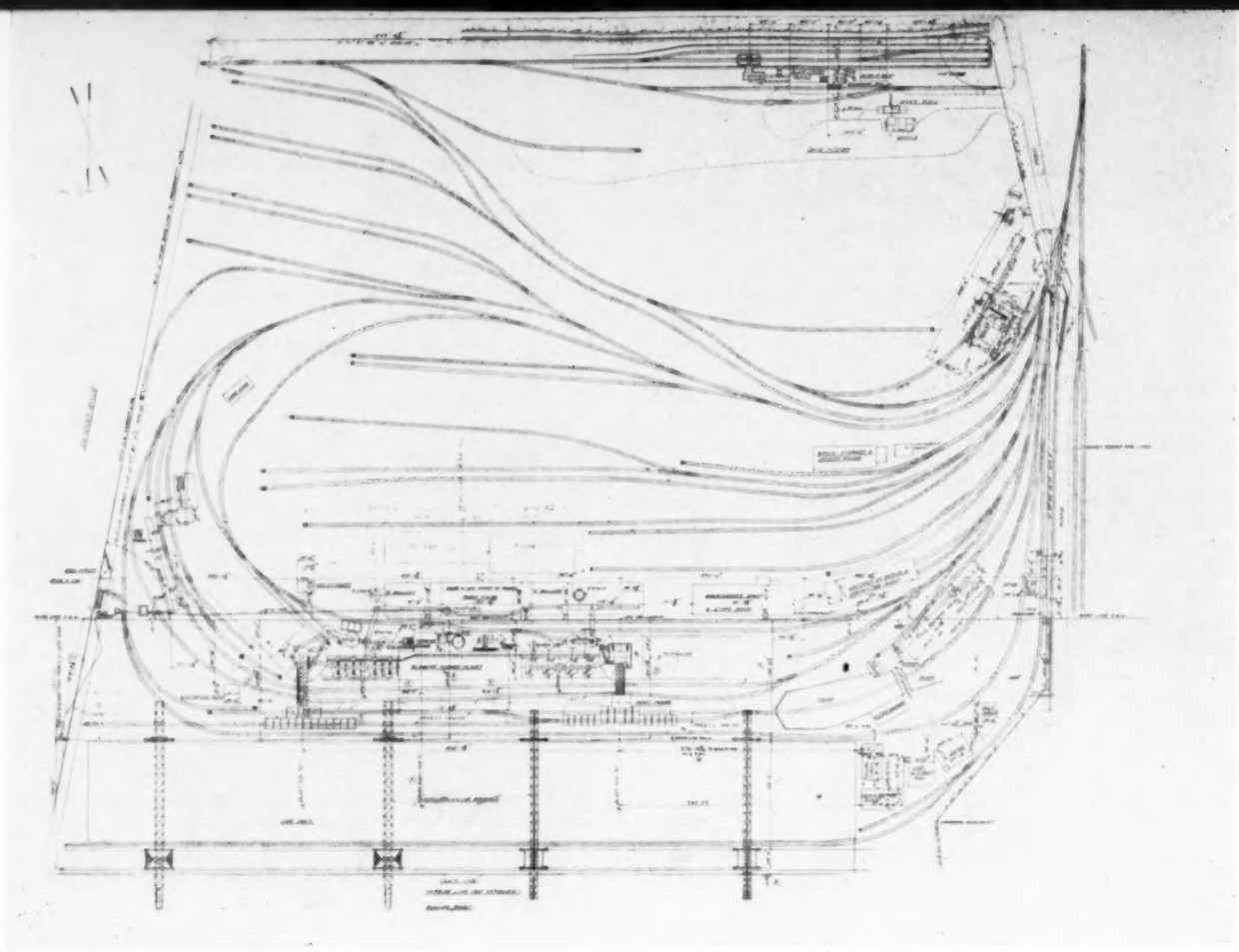
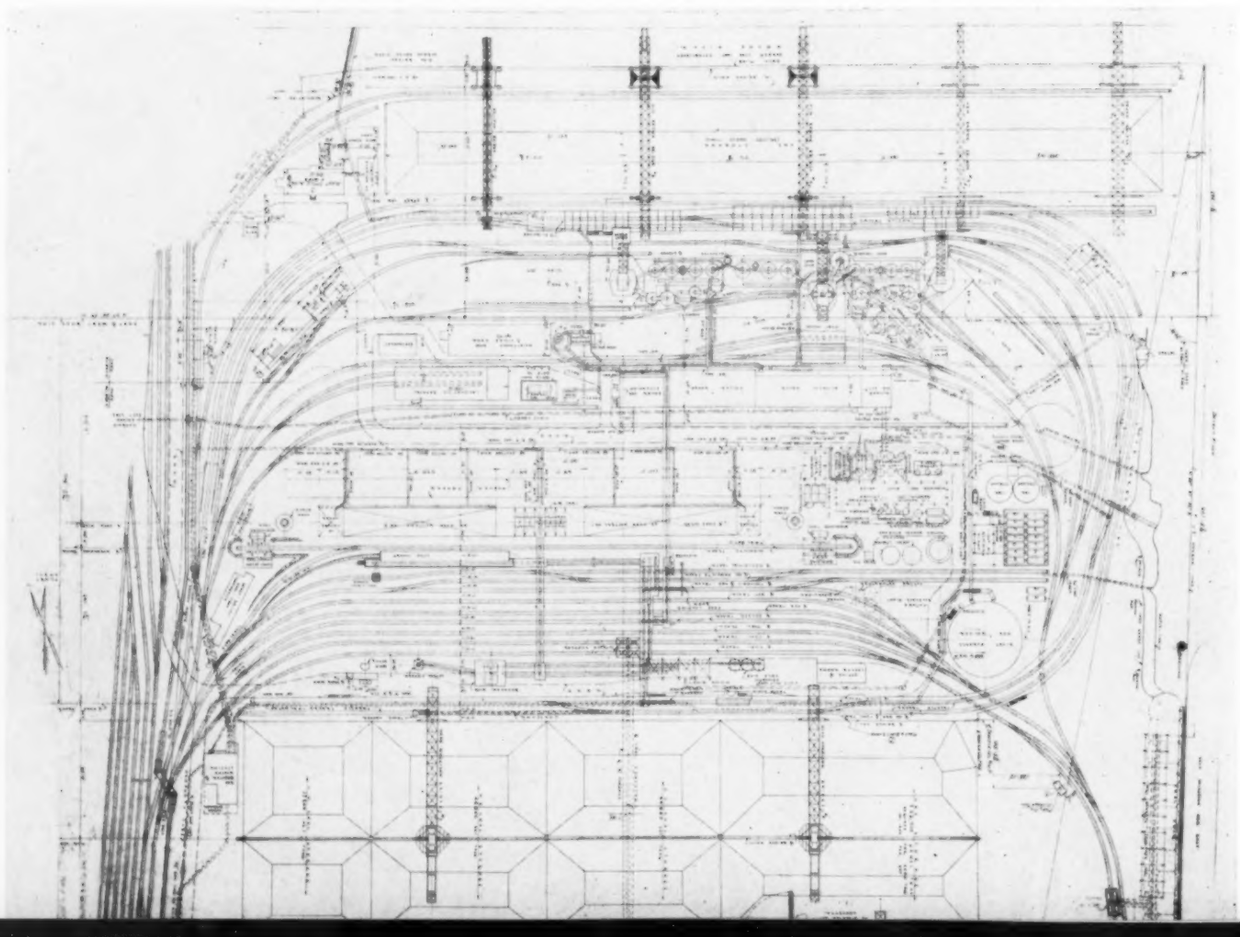


FIGURE 4—General layout of entire plant before installation of the new blast furnace and coke plant.

FIGURE 5—General layout of entire plant showing the completed installation of the new units.



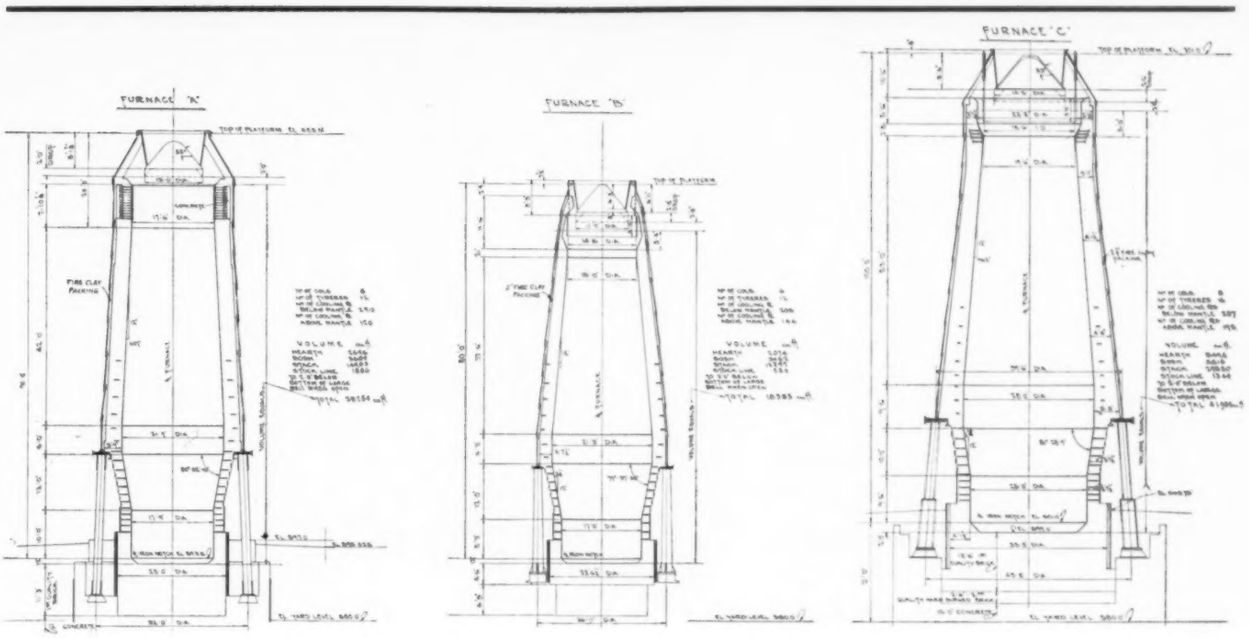


FIGURE 6—Diagram showing general lines of the three blast furnaces now in service at the Zug Island plant.

"B" furnace had to be removed to provide space for precipitators, and one of the first steps in the program was to work in a new gas washer for "B" furnace and relocate it to clear the site for the new precipitators, gas mains, etc. The outlet from the new "B" gas washer was arranged to tie in with a common header from the new "C" furnace washer and from then on into the precipitators. The quantity of gas from the two furnaces required large gas mains and these took up a considerable amount of very valuable space.

In order to make a suitable layout, it was necessary to locate the dust-catcher on the north side of the new furnace and to locate the gas washers and precipitators on the south side of "B" furnace stoves. The space immediately south of furnace "C" had to be used for the cast house; the space to the west for the stoves; and immediately south of the new stove foundations was the slag pit.

In other words, the space that had originally been occupied by the blowing engine house, the old pump house and part of the old boiler house was now filled solidly with the furnace, cast house, stoves and slag pit. While the layout is very compact, it has proved to be very serviceable.

PILING AND FOUNDATIONS

After determining the foregoing general plant layout, we next turned to some of the details of the construction that made the job very interesting.

When the old blowing engine house, pump house and other equipment had been removed and the foundations dismantled, the old wood piles were still in the excavation and had to be removed, since their capacity to carry load was but a fraction of that required for the new furnace stoves, etc.

At our site on Zug Island, the Detroit River has an average level, according to the Government bench, of 572 ft. Previous to the time the first blast furnace was

FIGURE 7—View showing the dismantling of the old engine house, with "B" furnace in the background.

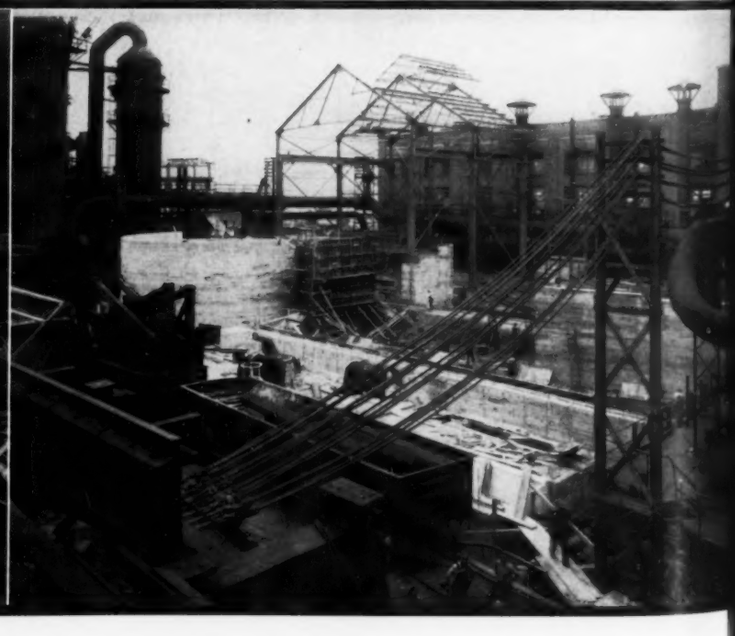
FIGURE 8—Another view of the dismantling process of the old engine house.

FIGURE 9—Piles 70 to 77 feet long support the reinforced concrete furnace pad.

built, part of the site was below the river level, and this site had previously been filled in with sand or slag to provide a yard above the water level. The ground along the Detroit Rover is mostly soft blue clay down to hard-pan, which is usually 72 to 80 ft. below the yard level. However, at the blast furnace plant a strata of sand is encountered about 30 ft. below yard level. This sand strata extends down for a distance of about 30 ft., below which soft blue clay is again encountered; and this clay then extends down to hard-pan.

FIGURE 10—View of the forms for the circular reinforced concrete foundation of the furnace.

FIGURE 11—View showing the finished furnace foundation, with stove foundation and slag pit wall in foreground.



The old wood piles under the original equipment had been driven to the sand strata and were only about 35 ft. long. The job of pulling out these old piles proved to be quite a simple matter. After erecting a suitable hoisting rig, the piling contractor simply slipped a cable sling around the butt end of the old pile; and they pulled out with little difficulty, much on the order of pulling your boot out of the mud. The old wood piles were in good condition. Some still had the bark on them, after having been in the ground some 35 or 36 years.

Due to the high concentrated loads for the new furnace, stoves, dust-catcher, etc., it was decided to install step-taper piles. These piles varied in length from 70 to 77 ft. For those who are not acquainted with this type of pile, wish to mention that the point or the part first driven in the ground in a 10 in. steel pipe. This steel pipe is usually welded together to suit the length of pile required. The top section of the pile, or the last part driven, is very similar to the conventional concrete pile; that is, the casing is made of sheet steel, and where it joins the steel pipe a special locking ring is used.

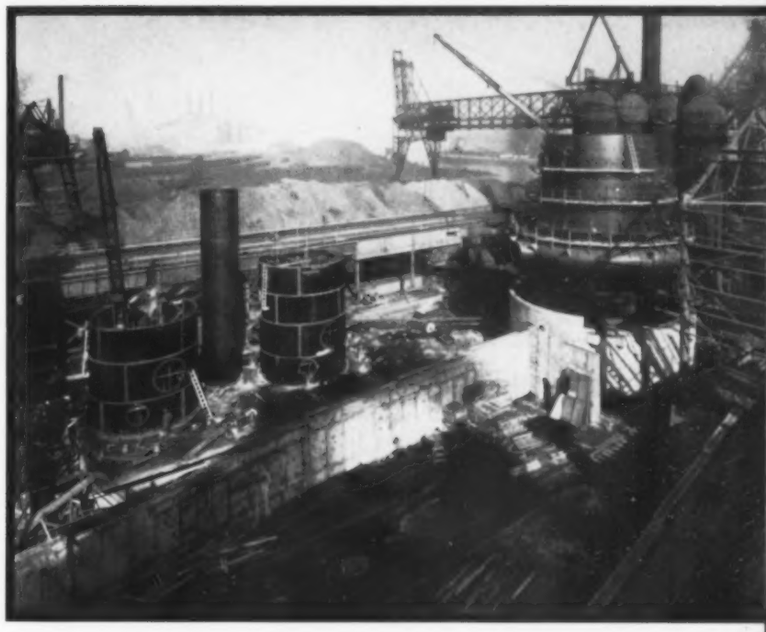


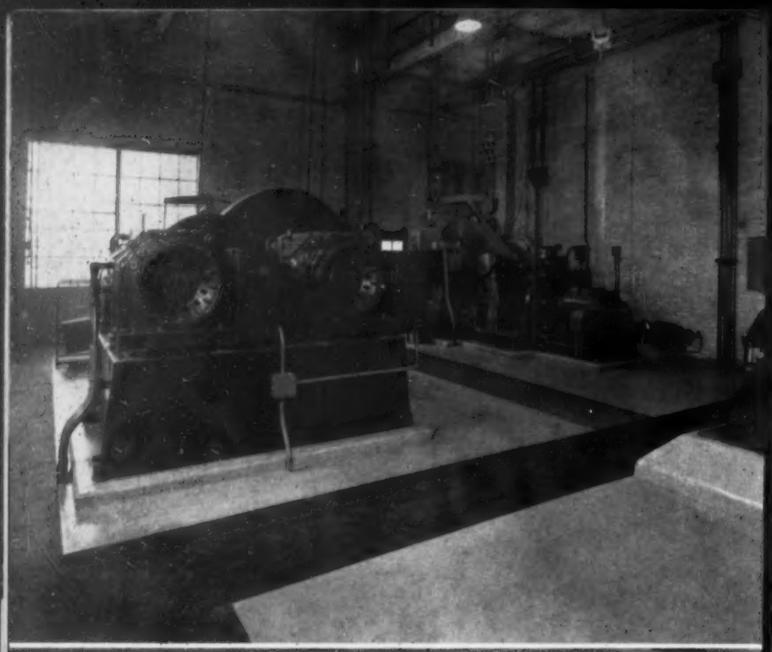
FIGURE 12—View showing completed foundations and the erection of furnace shell and two stove shells.

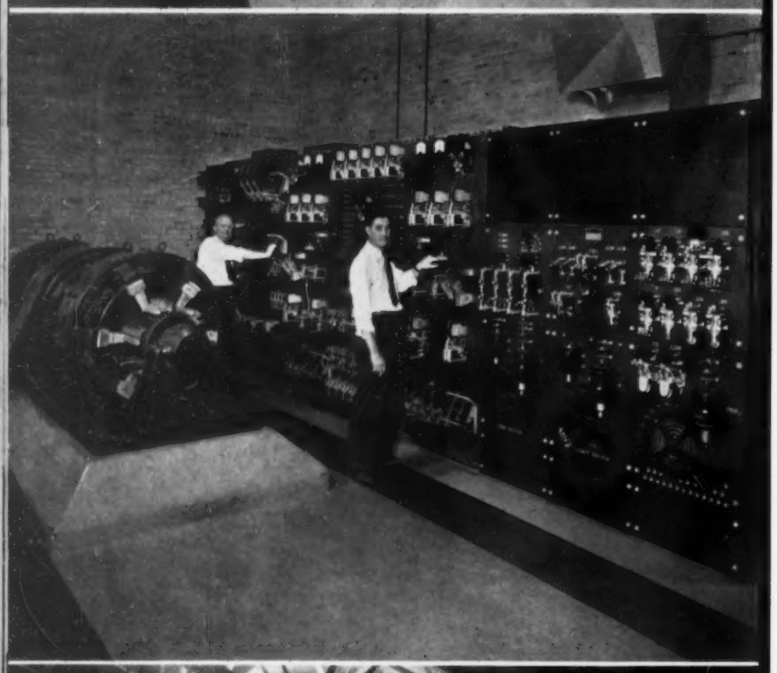
FIGURE 13—Operation of the revolving distributor is electrically interlocked with skip and bell hoists.

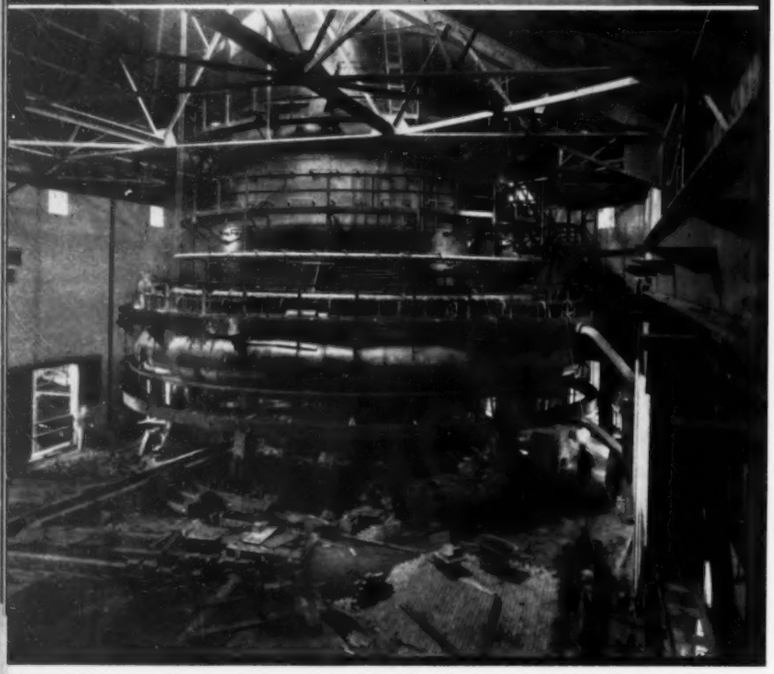
Usually, this upper sheet steel section is 30 to 35 ft. long. After the pile is driven and inspected, it is immediately filled with concrete. This type of pile has been tested out to carry 100 tons; but, in this case, we loaded them to about 45 tons.

By using this type of pile we were able to keep the

FIGURE 14—The large bell beam is operated from the hoist below, through cables attached to chain linkage.







size of our concrete foundation within reason. Previous experience at Zug Island, as well as at our steel plant site at Ecorse, has dictated that wood piles are economical when the loads to be carried will permit the design of a pier with footing of reasonable size. When, however, the loading is such that footings are spread over a great area to cover piles of lesser carrying capacity, it is more economical to use concrete filled piles and confine the footing to lesser dimensions. Were wood piles used in this instance, the footing spread would be such that additional piles would have to have been driven to simply carry fill over the footing; and, due to the confined area in which this furnace was built, it would have been impossible to have installed footings of greater spread than required by concrete piles.

The concrete piles under the furnace proper are on 36 in. centers in both directions. For the new blast furnace, stoves, dust-catcher, cast house, stock house, slag pit, etc., we drove 1409 step-taper piles. This number of piles was actually needed to carry the load. The percentage of pile failures, due to crushing of the top section, or piles not driving straight, was about four per cent. We believe this to be remarkable when it is considered that a good many of the piles were driven through slag, which had been poured in this location in the early days of the plant. A great deal of care and attention was of course given to the driving of these piles to keep failures to a minimum.

The foundations under the furnace proper were given a lot of thought; we debated at considerable length as to the depth of concrete under the hearth. Due to ground conditions, we had a problem very different from furnaces in other localities. We finally decided on a 15-ft. slab under the furnace, which was made in a continuous pour. The lower 6 ft. of the slab, which is of octagon shape, has no reinforcing other than that placed over the piles. The circular section above the octagonal pad is 56 ft. 6 in. in diameter and is reinforced as a hoop.

At the 15-ft. elevation above the piles the concrete slab is stopped off, but the outside walls are carried up to the cast house floor level, making a hollow tub in which the furnace is built. Incidentally, this circular section of foundation below the cast house floor and down to yard level is completely exposed outside the tub; no fill is placed around the furnace foundation above the yard level.

FIGURE 15—Skip hoist, bell hoist and their controls are located in a hoist house at cast house floor level.

FIGURE 16—The skip hoist is controlled through a variable voltage system, using a special motor-generator set.

FIGURE 17—Construction view of the furnace bosh and interior of cast house, showing cinder runner to the left.

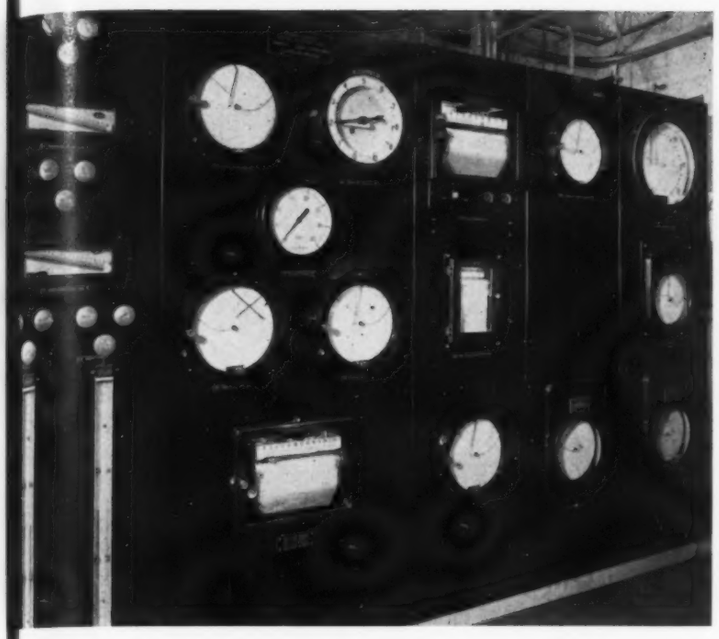


FIGURE 18—The instrument room is on the cast house level, and contains a complete layout of instruments for furnace operation.

The inwall batter is .962 in. in 12 in.
The bosh angle is 81 degrees–28 min. 9 sec.
The large bell is 14 ft. 6 in. in diameter and has a 53 degree angle.
The small bell is 6 ft. 0 in. in diameter.
The furnace is 102 ft. 8 in. from the hearth level to the top of the flange on the large bell hopper.
The volume of the furnace is as follows:

Hearth	5,494 cu. ft.
Bosh	5,521 cu. ft.
Stack	29,580 cu. ft.
Stockline	1,344 cu. ft.
Total	41,939 cu. ft.

This volume is figured from the bottom of the large bell in open position to the hearth level.
The furnace has 8 columns and 16 tuyeres. The eight columns are 14-inch H-beams weighing 426 lb. per ft. with 2-inch thick cover plates on the flanges.

BUSTLE PIPE

The bustle pipe is 4 ft. 0 in. in diameter inside of brickwork and is lined with two 4½-inch courses of brick with 3 inches of insulation against the shell.

FURNACE BRICKWORK AND DIMENSIONS

We have 15 ft. of bottom brick under the furnace hearth. This consists of 2½ ft. of hard-burned second-quality brick on the top of the furnace foundation and 12½ ft. of first-quality bottom blocks above this. This 12½ foot depth of bottom blocks was made in lifts of 22½ in., the size of the brick being 13½ x 6 x 3, and 9 x 6 x 3, all ground to size.

Due to the fact that the slag from the furnace flows directly into the slag pit adjacent to the cast house, it was quite a simple matter to provide means to drain the salamander from this furnace. A bricked-in opening of considerable size has been provided through the furnace foundation and so located that the salamander can be drained directly into the slag pit.

The following are a few of the characteristic points and dimensions on the furnace:

The inside diameter of the hearth jacket cooling plates is 33 ft. 3 in.
The inside diameter of the tuyere breast is 30 ft. 3 in.
The furnace columns are set on a 43 ft. 8 in. diameter circle at the base and a 39 ft. 6 in. diameter circle at the mantle.
There are ten rows of cooling plates below the mantle and eight rows of cooling plates above the mantle.
The furnace is now lined to a 25 ft. 0 in. diameter hearth, 28 ft. 0 in. bosh, and 19 ft. 6 in. diameter top. The top is expanded to 22 ft. 2 in. diameter behind the suspended stockline wearing ring, which is 18 ft. 6 in. inside diameter.

FIGURE 19—View of temporary trestle which was built to allow transportation to "A" and "B" furnaces during the construction period.

The furnace is equipped with an electric mud gun and mechanical cinder notch stopper.

FURNACE TOP

The furnace top is equipped with a revolving distributor, the operation of which is electrically interlocked with the skip and bell hoists through the usual furnace sequence control.

The large bell mechanism is arranged for positive opening of the bell through rigid linkage, consisting of a bell beam which imparts motion to the bell rod through a link extending to a crosshead and guided roller at the upper end of the bell rod. The bell beam is operated by the hoist below through cables attached to chain linkage over the end of the bell beam. The opposite end of the bell beam is attached to the counterweights at ground level by cable. The chain linkage over the end of the bell beam is made of heat-treated SAE-3140 steel, is of large section, and does not require lubrication.

The small bell mechanism consists of a bell beam on the furnace top on which the counterweights are mounted. The end of the bell beam is attached to the hoist by cable.

HOIST HOUSE

The skip and bell hoists, as well as the furnace control panels, are located at the trestle and cast house floor level, the hoist house being partly under the skip bridge.

FIGURE 20—General view of new furnace and stoves. To the left is an elevator tube serving "A" and "C" furnaces.

J. G. West, Jr., and E. J. McCleary shown at the technical session.

To prevent the infiltration of dirt into the hoist house and to provide clean air for the cooling of the apparatus located therein, a filtering and conditioning system has been provided underneath the house from which the cleaned air is conducted to the hoist room above.

The bell hoist, which has been referred to previously, is of the single-unit type, driven by a 68-horsepower d-c. motor.

The skip hoist is of the geared type, operated by two motors.

Of vital importance to the modern blast furnace of this size is a properly designed skip hoist. There are three types of electric hoists in use today. They are:

First, the slow-speed, d-c. motor, direct connected, gearless type, with rheostatic control; excellent for small furnaces, but as a rule prohibitive in price.

Second, the small high-speed d-c. motor, geared to hoist, with rheostatic control. In the past this type has been considered the best in blast furnace skip hoist controls.

The third type, which we have installed on this furnace, as previously stated, is the geared type driven by two 150 horsepower d-c. mill-type motors, each direct connected electrically to two 150 kw. generators driven by one 400 horsepower, 440 volt, 3-phase, 60 cycle induction motor. With this arrangement, the possibility of a motor or generator burn-out does not shut down the furnace. For a period of approximately one hour the furnace can be run at full capacity with one generator or one motor out of service. After this period, a slow-up will have to be made until the damaged equipment can be repaired or replaced.

L. R. Milburn and C. C. Wales, on the inspection trip through the plant.

The question might be raised as to why only one a-c. motor is used to drive the two generators. We would answer that in this way: The induction motor is the most sturdy electrical device that is known today, and the possibilities of failure on the induction motor are so remote that it was not deemed necessary to have two of them in this electrical hook-up. We do, however, carry a spare stator for this equipment.

Having described the equipment, we will now give you the duty-cycle of this machine:

4 seconds to accelerate
21 seconds of high-speed travel
3 seconds retarding to 75 ft. per min.
8 seconds running at 75 ft. per min.
1 second for stopping.

This is an excellent operating time chart when you consider that the maximum speed is 600 ft. per min. with an angle of skip-way with horizontal of 56 degrees and a skip-travel of 198 ft. The maximum load which this skip will handle is 22,500 lbs.

The electric control of this equipment is of the variable voltage type, and from its original installation has functioned perfectly. The skip can be controlled from two points, at the operating point over the skip pit and from the hoist house itself. The normal operation is of course from the operating pulpit over the skip, which we will mention later in connection with the stock house.

CAST HOUSE AND INSTRUMENT ROOM

The cast house is south of the furnace and is arranged so that the hot metal cars pass under the cast house floor. The runners are arranged so that we can pour metal into four 110-ton mixer cars.

The instrument room is on the same level as the cast house and is readily accessible to the furnace blowers.

SLAG PIT

The slag pit is on the west side of the cast house and is arranged with tracks on either side. The slag is removed from the pit by an electric shovel and is put into cars on the above tracks for delivery to our slag plant.

STOCK HOUSE

The furnace stock house is equipped with 19 ore and stone bins, 1 scrap bin, and 2 large central coke bins. Half-inch wearing plates are installed in the bottoms of the ore and stone bins and 40-lb. rails are installed in the scrap bin. Two inches of concrete, reinforced with wire, is installed in the interior of the coke bins.

The scale cars are 200 cu. ft. capacity. The master controllers for the sequence control, signal lights, stock test recorder, etc., are located in an operator's pulpit directly above the skip pit. Coke is charged to the skip cars by volume after being screened over shaker screens.

The construction of the stock house was probably

FIGURE 21—Interior view of the new blower house, which serves all furnaces of the plant.

one of the most interesting features of the furnace construction in that it was necessary to build a temporary trestle around the stock house site and continue transportation to "A" and "B" furnace bins on either end of the new stockbin site. Needless to say, the furnace operating crew were pleased when this part of the construction was completed and trestle traffic was permitted to operate over the new bins.

HOT BLAST STOVES

To supply the necessary hot blast for the furnace, three large stoves have been installed.

The shells of these stoves are 24 ft. in diameter and 100 ft. high.

They are lined with modern small checkers for clean blast furnace gas. The checker openings are $1\frac{15}{16}$ in. square and have a $1\frac{1}{4}$ in. thick firebrick wall between openings.

The stoves are of the side combustion two-pass type and are equipped with pressure-type gas burners, each burner being designed to burn 15,000 cu. ft. of gas per minute.

Each stove has a total of 191,000 sq. ft. of heating surface and contains 460,000 nine-inch equivalents of fire brick.

The stoves are capable of supplying the furnace with a continuous hot blast of 1500 degrees F., and their operation is usually alternated so that each stove is heated for a period of four hours after heating the blast to the furnace for two hours. Air actuated automatic control is provided to maintain uniform hot blast temperature.

The three stoves are served with a common stack, which is 9 ft. 3 in. diameter inside of the bricklining and 200 ft. high.

The hot blast valves on these stoves are 4 ft. in diameter and are uncooled, the valve and stem being made of heat resisting alloy. The valve seats are bronze and are water-cooled. The hot blast main is provided with two expansion joints.

ELEVATOR

The compactness of the furnace layout, although having caused some inconvenience with operations during construction, has brought about many advantages. One of these has been in connection with the elevator installation. By locating the elevator between the end stoves on "A" and "C" furnaces, it was quite a simple matter to erect a walkway from the elevator landing to the top of both sets of stoves. A stairway was also erected between the top platform on "C" furnace and the platform at the top of "B" furnace stoves. This has made all three furnace tops accessible from the one elevator.

The following is the charging sequence used in the operation of this furnace: ore, ore, coke, coke, limestone, borings and flue dust, coke. This comprises seven skip loads, after which the large bell is dumped.

The weight of materials in each charge is as follows:

Ore	38,800 lb.
Borings	1,700 lb.
Flue dust	2,200 lb.
Limestone	8,400 lb.
Coke	17,100 lb.
Total	68,200 lb.

There are 1,765 lb. of coke being used per ton of iron, ten per cent of which is nut coke. The furnace is being blown with 64,000 cu. ft. of wind per minute.

The furnace has been in blast since August 16, 1938.

DISCUSSION

PRESENTED BY

A. J. BOYNTON, Vice-President, H. A. Brassert and Company, Chicago, Illinois.

F. E. KLING, Assistant Chief Engineer, Carnegie-Illinois Steel Corporation, Pittsburgh, Pennsylvania.

A. J. BOYNTON: This is the second occasion of this kind that I have attended within a month, both under the auspices of this society. I had the pleasure of making a trip to attend the Birmingham meeting, and now this meeting tonight. This trip has been a pleasure to me, and I want to say that I intend to make the trip to Youngstown, if at all possible. I think that these inspection trips with the papers which have accompanied them, both in Birmingham and in this case, make a program which is of very great interest to all engineers.

It has been a great pleasure to me this afternoon to see this very good job of construction, a job which is a source of credit and pride to anyone who had anything to do with it, both in regard to its inception and in regard to its details, insofar as anyone is able to judge them in one afternoon's inspection.

In view of the number of people who want to discuss these papers here tonight, I don't want to say too much. With regard to this new 1,000-ton blast furnace and similar construction, it is to be noted that the construction of the blast furnace is a thing which necessarily changes very little from one individual installation to the next on account of the nature of the process and the uncertainties that attend any radical change in design. Designs tend to become crystallized and changes are made with a good deal of consideration and caution.

Nevertheless, I venture the prediction that there will continue to be changes of very considerable importance,

which will be made gradually, but nonetheless surely. Without attempting to discuss these, I will take just a moment to recount what some of them seem to be.

With regard to the matter of the air blown into the furnace: It is very often stated that the air is the most important element in the operation. Judged by weight, only, this is true. Some 7,000 pounds of air go into the manufacture of a ton of pig iron. All this air is measured in its total amount; it is not measured at the individual tuyeres of the furnace. Whenever it becomes advisable or necessary to do that it can be done, and it requires nothing in the way of modification of present construction other than the provision of a sufficiently long straight section of tuyere stock to enable a measuring orifice to be correctly placed. I do not think that there will ever be occasion to make this measurement continuously as a feature of routine operation, but in the case of a new furnace, it may be well and worthwhile to make this measurement for a long enough time to find the characteristics of air distribution, as determined by stock distribution and by the size and arrangement of the air piping.

Then secondly, the matter of the moisture in the air is receiving attention again. There was a contract let by the Woodward Iron Company the other day, which was announced at the Birmingham meeting, on what they called "air conditioning to three grains of water vapor per cubic foot of air". The Gayley refrigeration system, in the years 1905 to 1910, whereby the moisture was reduced, was similar in its purpose. Air conditioning, as practiced with the earlier equipment, was too expensive to be economical. In the present case, the problems are not different from those that are ordinarily solved in air-conditioning.

With regard to the heating and temperature of the blast, we have most effective means for doing that. The difficulty in fully utilizing the efficiency of this apparatus results from the fact that the high temperature obtainable is not usable all the time. My own idea is that the time will come when a high blast temperature will be continuously used, and that unquestionable fuel economies will be derived from use of such blast temperature. But there will also be considerable changes in other resultant matters, such as the value of the blast furnace gas.

One of the possibilities which has been receiving study that may lead to the possibility of a full use of blast temperature, is the possibility of changing the method of the feeding the stock into the furnace, so as to maintain a greater degree of separation than is now possible between fine limestone and fine ore. That is, to charge a part of the limestone into the middle of the furnace with the idea of preventing the formation in the furnace of ferrites of lime, which become fluid within the furnace, and later become stiffened up as the reducing power and the temperature increases, with an interval between the time that this stiffening of the primary slag occurs and the time when combustion of the coke adds the necessary silica and alumina to make the final slag.

This has been, as I said, receiving a good deal of attention, and some investigation has been made on a laboratory scale by investigators who have received well-deserved credit for similar investigations in the past.

One thing which is mentioned in this paper is the use of coolers in this new furnace. I think one reason why these stack coolers haven't been more widely used is the fact that there has been some difficulty in producing the effect that is wanted, and there is very considerable room for improvement with regard to design of inwall coolers.

Shown at the dinner which preceded the technical session are F. E. Caskey, J. W. Irwin, W. J. Rees, R. M. Hughes, L. R. Milburn, C. C. Wales, P. C. Vetter, E. F. Weiss and Brent Wiley.

At the top of the furnace, a very considerable improvement has been made in recent constructions with regard to the form of down-takes and primary dust-catchers. This is exemplified in the present construction.

The only other thing to which I wish to call attention is the desirability of simplifying the construction of the head frame and the top structure by locating the bell handling equipment on the top of the furnace, and controlling it from below.

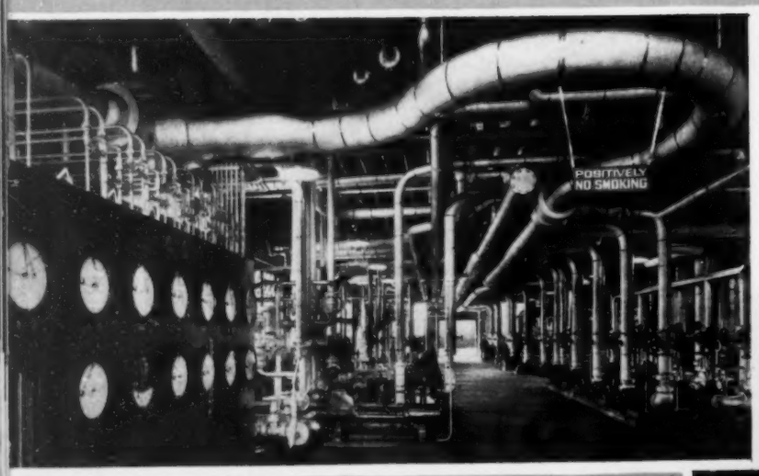
F. E. KLING: I was particularly interested in the new blast furnace, which appears to be a very good job. Breaking away from the conventional cast iron columns by using heavy rolled steel sections is a step in the right direction.

GREAT LAKES STEEL CORPORATION

Choos

Right—General View of Plant

By-Product Recovery Apparatus



Above—By-Product Pump Room

Right—Light Oil Refining Plant

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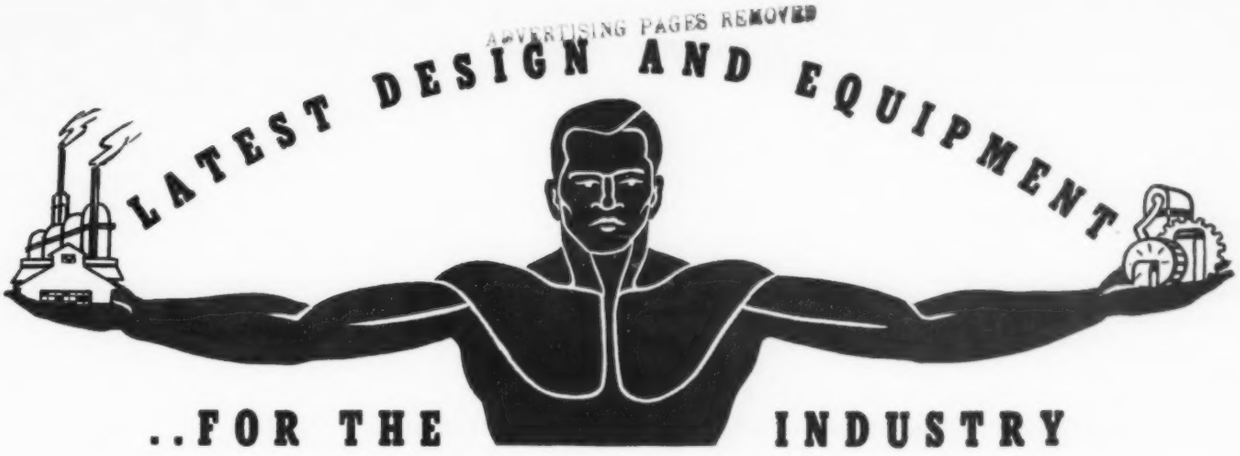


WEIRTON EXPANDS STRUCTURAL MILL AS PART OF $5,000.000 RECONSTRUCTION PROGRAM

▲ Weirton Steel Company is in the process of reconstructing their structural mill. This reconstruction work will make possible an increase of more than 200 per cent in this mill's potential finished tonnage. The new mill, which is part of a $5,000,000 expansion program, is expected to be completed and in operation on July 1. In the construction of the new mill provisions are being made to enable a further substantial increase in its output with but slight alterations.

The new plant will greatly expand the range and sizes of structural products of the Weirton Steel Company. In addition to all present products, nine entirely new products will be made and a number of present products will be rolled in a greatly increased range of sizes.

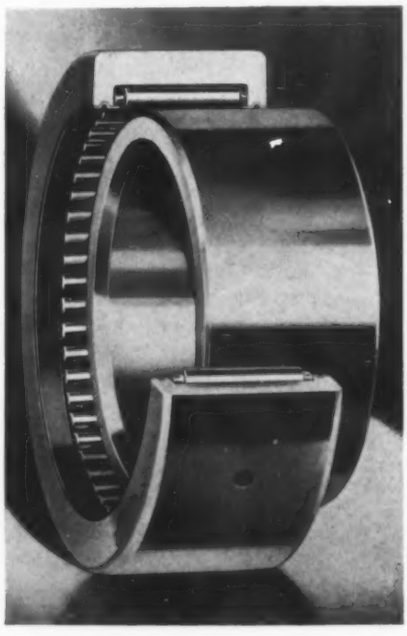
Included among the facilities of the structural mill will be a warehouse building recently erected on a site adjacent to the main office building. This building adds 110 by 528 feet to the present structural mill warehouse space. The additional space will allow greater flexibility in the operation of the structural mill and also make it possible to have products of the mill continuously available.

BEARING FILLS HEAVY DUTY NEEDS

▲ A new line of self-contained quill roller bearings designed for heavy duty service, but still of such proportion as to retain advantages of this type bearing—small space requirement, high load carrying capacity and economy, has been introduced by the Bantam Bearings Corporation of South Bend, Indiana.

No radial load can be exerted on roller trunnions or retaining bands in

Compact, economical and rugged, this bearing has been successfully applied to high-speed applications.



STEEL CAPACITY AND EMPLOYMENT RISES

▲ Between 1926 and 1938, 14 new blast furnaces were built, averaging 2½ times the capacity of the furnaces abandoned during the same period. In addition, 12 entirely new steel ingot plants and 42 new plants for producing finished steel have been constructed since 1926. The industry's present capacity for producing steel is 30 per cent greater than in 1926, while its capacity for producing pig iron, which has become relatively less important as a steel-making material, has remained steady.

During the same period the total number of employes in the steel industry has sharply increased. A new peak for the number employed in the industry was established in 1937, indicating that the improved technology of steel production has not decreased employment, while the total number at work in 1939 is substantially higher than in 1926. These facts were determined by the American Iron and Steel Institute from a study of reports furnished by companies in the industry.

Fewer than a dozen plants were abandoned as a direct result of mergers or consolidations despite the fact that the steel industry has abandoned or dismantled 173 blast furnaces, 39 plants for producing steel ingots and 144 plants for producing finished iron and steel products. This decline in productive capacity from the abandonment of obsolete equipment was more than offset by the construction of new and more efficient plants and by the modernization of existing facilities.

operation, it is said. Retaining bands are spring steel, definitely located and fastened in grooves in outer race ribs. Race is a single channel-shaped piece, hardened and ground to precision limits. Ribs, an integral part of the race, provide solid abutment for ends of rollers.

Lubricant is supplied to bearing through oil holes in outer race. Bore of outer race ribs is held relatively close to inner race outside diameter to help maintain lubricant supply within bearing. Straight inner races are used, allowing installation of inner race separately from outer race. Inner race can be eliminated where shafts are properly hardened.

This series of bearings is designed for maximum number of correctly proportioned rollers, and roller trunnions are made with largest possible diameter, thus providing maximum end surface. These bearings have been applied successfully where theoretical roller speeds exceeded 60,000 revolutions per minute.

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When manufacturers place their stamp of approval on DOLPH Insulating Varnishes and Compounds, it is only logical that these same materials should be specified when the equipment has to be repaired. In the steel industry where costly shutdowns cannot be tolerated, it pays to use DOLPH'S Insulating Varnishes. They have proven their ability to keep production equipment on the job.

If there is ever any doubt as to the correct grade to use for any particular transformer, DOLPH technicians will be glad to make recommendations without obligation upon receipt of detailed information regarding the unit.

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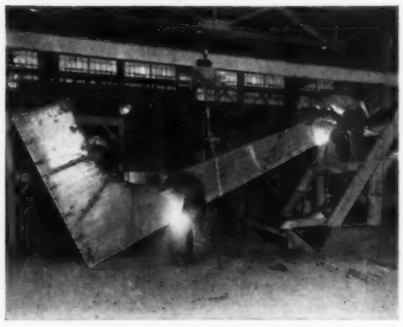
ALL-WELDED GANTRY CRANE

▲ Manufacturers building machines for lifting, lowering and moving loads are adopting rapidly the use of all welded alloy steels because of the increased mobility due to lighter weight and the greater strength any all-welded construction provides. Harnischfeger Corporation recently completed what is said to be the only all welded gantry crane of its type ever constructed. Designed for lifting gates on a large dam, this 20-ton capacity crane measures 22 feet in height, and required 1250 lb. of ¼ inch electrodes. Harnischfeger used its own welding equipment and electrodes in the manufacture of this crane, and the resultant weight savings will amount to about 25 per cent, with the strength increased considerably. The welds have a tensile strength of 60,000 lb. per sq. in., elongation of 25 to 35 per cent in 2 in., and impact resistance of 40 to 60 ft. lb.

This company, manufacturers of a complete line of electric arc welders and welding electrodes, announce a new square frame welder for multi-arc service. Representing the last word in simplicity, compactness, ease in operation, this is a precision built welder with a design enabling it to be built with the practical economies of modern mass production. It requires a floor space of less than 3½ sq. ft., and offers a welding range from 40 to 225 amps. Retaining all the inherently fine characteristics made possible by the Hansen patents which cover automatic volt-ampere regu-



Complete welded construction of this gantry crane reduced weight about 25 per cent.

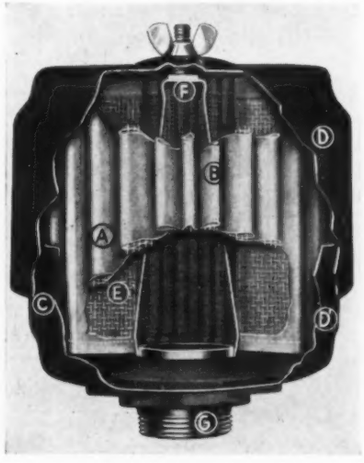
lation, self-excitation and internal stabilization of the welding current, the new model is built along extremely simple lines, having but two major parts, the one piece frame and the rotating member itself. All attachments such as external exciters, reactors, resistors, rheostats or separate stabilizers are absent.

A double-duty gas and electric welding unit has been also recently introduced. The combination includes a 150 ampere portable welder manufactured by Harnischfeger, and the gas equipment which is manufactured and developed by the Young Sales Company, Inc. This unit, representing the very latest development in the combination gas and electric portable welder, can be used with complete gas welding and cutting equipment.

NEW DESIGN OF AIR FILTER

▲ Embodying all the well-known "Protectomotor" principles a new "Protectomotor" air filter has been developed by the Staynew Filter Corporation, for use on small internal combustion engines, compressors, pumps and all air breathing machines. Offering important economies, particularly in volume purchases, the air filter is amply protected against all weather conditions by the heavily enameled steel housing opening at the bottom. This steel housing, of simple pressed metal construction, is less expensive than the aluminum louvred shell of the model which is now superseded by this new Model E. At the same time the new model possesses every advantage of its predecessor.

Improved design of air filter provides important operating economies.



NEW INDUSTRIAL TRUCK TRACTOR

▲ Compact, fast, and easy to manipulate, Elwell-Parker Electric Company's new industrial truck-tractor has a rated capacity of 3,000 lb., and has four speeds forward and four reverse. The frame is made up of heavy section formed plates welded

CLEVELAND CRANES

ARE

ALL WELDED CRANES

INCLUDING GIRDERS

FOR MAXIMUM RIGIDITY AND PERMANENT ALIGNMENT

Three 15 ton 100'-0" Span Cranes in a Modern Sheet Mill

ALSO BUILDERS OF CLEVELAND TRAMRAIL MATERIALS HANDLING EQUIPMENT

THE CLEVELAND CRANE & ENGINEERING CO.

1131 Depot St.
WICKLIFFE, OHIO.

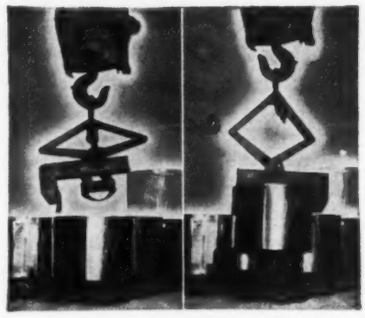
NEW YORK DETROIT PITTSBURGH CHICAGO

into rugged one-piece construction including control dash and pedal guard. The platform is fitted with detachable end gate which may be adjusted so as to carry additional load. Provision is also made for the truck to pull trailers.

In this new truck safety to men, machine and hauling loads has been emphasized. As an example, pedal guard protects operators legs, dynamic brakes supplement the travel brake.

NEW DEVICE FOR COIL HANDLING

▲ Tongs for handling strip coils have been developed by the Heppenstall Company, with the idea of eliminating damage to the edges of thin steel strip during handling. Power failure will not affect the lifting and holding properties of these new tongs. When the tongs are lowered and come in contact with the coil, release mechanism automatically operates, and jaws grip coil as the tongs are raised. When the coil is deposited in a new location, the tongs automatically release and again lock in open position.



New design of tongs eliminates handling damage to coils.

The relatively light weight of the tongs permits the handling of thin strip without the usual danger of damage to the edges. Pairs of coils may also be handled in the same manner as a single coil.

RATE OF FLOW INDICATOR.

▲ A new flow recorder operating to indicate and record instantaneous values of rate of flow as measured by displacement meters has been developed by the Bailey Meter Company. This device, which employs an electrical transmitting method, differs from the usual flow recording attachment for displacement meters in that it draws a graph of rate of flow against time instead of simply recording total flow over a given time. It is attached to the displacement meter body by employing the flange bolts.

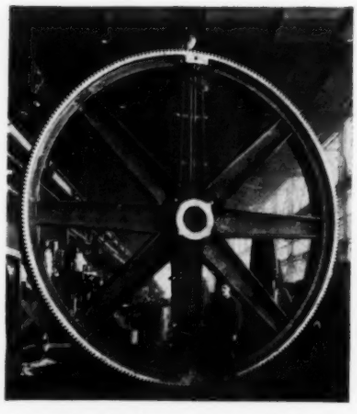
The displacement meter register is raised by a filler block to afford room for bevel gears and a short shaft extension is used to drive the register of the displacement meter. The bevel gears drive a shaft which operates the synchro-meter unit. No change or modification of parts of the displacement meter is required for the attachment of this device.

BIG GEARS *and* LITTLE ONES

Farrel-Sykes Gears Made in Any Size

Whether large or small gears are required Farrel-Sykes Continuous Tooth Herringbone Gears are made in a complete range of sizes to meet all needs. They can be supplied in any size up to 22 feet in diameter and for any power capacity.

Throughout their entire size range Farrel-Sykes Gears are *engineered* to the job they have to do—their continuous herringbone teeth give them extra strength and load-carrying capacity to withstand shocks, stresses and wear. The combined characteristics of gradual engagement of the teeth, overlapping or interlacing of the teeth and inclined line of pressure, plus precision generation by the Sykes process, make these gears exceptionally quiet and smooth-running and increase their durability. The result is continuous high operating efficiency, minimum maintenance cost and long life.



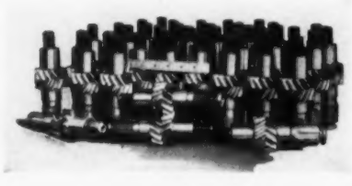
Farrel-Sykes Continuous Tooth Herringbone Gear for rolling mill drive, 217.480″ outside diameter, 25″ face. Transmits 800 H.P. at 360 RPM. Ratio of gear and pinion 18.12 to 1, speed of gear 19.85 RPM, peripheral velocity 1130 feet per minute. Total weight 44,900 pounds. Made of steel castings in two halves carefully machined and bolted together with fitted bolts.

●

Farrel engineers are available for consultation on gear applications. Their experience in solving many unusual drive problems may help with yours.

We also manufacture straight tooth and single helical gears in any size from ¼″ to 20′0″ diameter and are specially equipped to produce internal gears with either spur or helical teeth in any size up to 18 ft. diameter.

●



(*Left*)—Small Sykes Gears integral with shafts 8 ⅛″ long overall, 12 teeth, 6 DP, 1⅞″ face 2.413″ outside diameter. The greatest strength for the space available is obtained with these gears.

FARREL-BIRMINGHAM COMPANY, INC.

366 VULCAN STREET BUFFALO, N. Y.

FARREL SYKES GEARS

The Gear with a Backbone

ITEMS OF INTEREST

R. R. Smith
who has been general superintendent of the Ashland, Kentucky, division of the American Rolling Mill Company since 1930, has been made manager of this plant. He joined the company in 1912 as a foreman in the sheet mills, later becoming sheet mill superintendent. In 1922 he was transferred to Ashland where the world's first continuous sheet rolling mill was being constructed. When completed he was made responsible for producing the first sheets made by the continuous method, now in use in all large steel plants today. In 1925 he became assistant general superintendent of the Ashland plant. Mr. Smith succeeds F. E. Vigor, who is now general transportation manager.

R. G. Adair
assistant director of personal and public relations, has been appointed assistant manager of the American Rolling Mill Company's operations in Ashland, Kentucky. Mr. Adair has held several important positions in the company's personal and public relations activities, in which field the company has earned an outstanding reputation among American industries. Joining the company as a laborer in 1917, he became a foreman, safety engineer, and in 1930 assistant to the manager of the American Rolling Mill Company's Butler, Pennsylvania, plant. He was appointed assistant director of personal and public relations in 1937.

Other appointments at the American Rolling Mill Company are as follows:

K. C. McCutcheon
has been made general superintendent of the Ashland plant;

W. Fred Songer
was appointed as assistant to the general superintendent at the Middletown plant;

J. W. Paton
is now the special representative in charge of the American Rolling Mill Company's extensive properties at Ashland.

The following changes in personnel were recently made at the Carnegie-Illinois Steel Corporation, Gary, Indiana:

W. S. Mac Nabb
who has been superintendent of industrial relations, has been made assistant division superintendent, open hearths and central mills;

T. J. Griffin
formerly superintendent of the central mills, has been given the post of assistant to division superintendent, open hearths and central mills;

T. H. Sanderson
will be the new assistant to superintendent, rail mills. He formerly held the position of contact representative, metallurgical division, at the Chicago office;

Stanley J. Brown
formerly an inspection foreman, was made foreman of the finishing and shipping department of the rail mill;

Forest J. Smith
formerly assistant superintendent of industrial relations, will be superintendent of industrial relations;

Walter Bennett
was made assistant superintendent of industrial relations. Mr. Bennett was assistant to division superintendent, open hearths and central mills, in charge of personnel matters;

Edgar N. Yost
formerly assistant chief inspector, has been made chief inspector;

J. S. McMahon
who has been stripper and mold yard foreman at No. 3 open hearth, becomes assistant to division superintendent, open hearths and central mills, in charge of personnel matters.

C. C. Deck
has been appointed superintendent of the rail mill, Carnegie-Illinois Steel Corporation, Gary, Indiana, succeeding the late Grant Monk. Mr. Deck has been associated with the corporation since 1919 when he began as a special electrician at Joliet Works. In 1934 he was transferred to the South Works as a test engineer and worked in various capacities until his transfer to Gary as assistant superintendent in the rail mill on March 16 of this year.

H. F. Brier
who succeeds C. C. Deck as assistant superintendent of the Gary rail mill of the Carnegie-Illinois Steel Corporation, began at Gary in 1918 after serving for a number of years with Lemont Limestone Company. Since that time he has been employed as

R. R. SMITH

R. G. ADAIR

rail mill inspector, section inspector, and operator and mill foreman until February 1, 1939, when he was appointed general mill foreman of the rail mill.

Luke E. Sawyer
formerly assistant general superintendent of the Babcock and Wilcox Tube Company, Beaver Falls, Pennsylvania, has been appointed general superintendent succeeding J. Frank Frain, who is now assistant superintendent, merchant bar mills, Carnegie-Illinois Steel Corporation, Gary, Indiana. Mr. Sawyer has been a member of the Association of Iron and Steel Engineers since 1922.

J. H. Morrison
has been appointed superintendent of hot rolling operations of Pittsburgh Steel Company's Monessen and Allenport, Pennsylvania, plants. Mr. Morrison, who joined the company in 1936, has been superintendent of the hot rolling works in Monessen. He formerly was with the Sharon Steel Corporation.

Parker F. Wilson
has been elected president of the Pittsburgh Steel Foundry Corporation, Glassport, Pennsylvania. Mr. Wilson was formerly with the Wheeling Steel Corporation and the Otis Steel Company holding various executive positions.

E. E. Tross
for the past seven years general superintendent of the Youngstown plant of the United Engineering and Foundry Company, has been appointed district manager at Youngstown, succeeding George W. Knotts. Mr. Tross returned two months ago from Great Britain where he finished building the largest steel plant in the British Isles which Mr. Knotts started three years ago.

T. J. Fleischer
was appointed general sales manager for the Walker Electrical Company of Atlanta, Georgia. Mr. Fleischer has been connected with the Crouse-Hinds Company for a number of years and is well-known in the South. Mr. Fleischer, who has been an Associate Member of the Association of

(Please turn to page 58)

T. J. FLEISCHER

a Note of Thanks..

TO THE

IRON AND STEEL INDUSTRY

• When the Thompson Lamp Lowering Hanger made its appearance 27 years ago, the makers of Iron and Steel were the first to recognize its advantages, and to utilize them. As in many other things, other industries followed after, but Iron and Steel continue to be the largest users of Thompson equipment . . . and also the severest critics.

For the very conditions that created the need for Thompson hangers, created a problem for Thompson engineers. The dirt and corrosion that attacked lighting fixtures, did not spare the disconnecting and lowering equipment, but thanks to the cooperation and valuable assistance of men in the Industry, today, Thompson Electric is able to announce a line of equipment longer lived, smoother to operate, and with a greatly increased range of application.

Thus we express our appreciation to the Industry both for its patronage, and for the help it has given us in the development of our products to new high standards. Naturally, we want you to know about the new Thompson line and we have issued a catalogue describing the equipment and featuring new uses. If you haven't the new catalogue, we invite you to ask for it, either from an electrical distributor, or from us.

Thompson equipment is listed in MacRae's Blue Book, Thomas Register, and the new issue of Sweet's Industrial Catalogue Files. It is sold through leading electrical distributors.

THE THOMPSON ELECTRIC CO.

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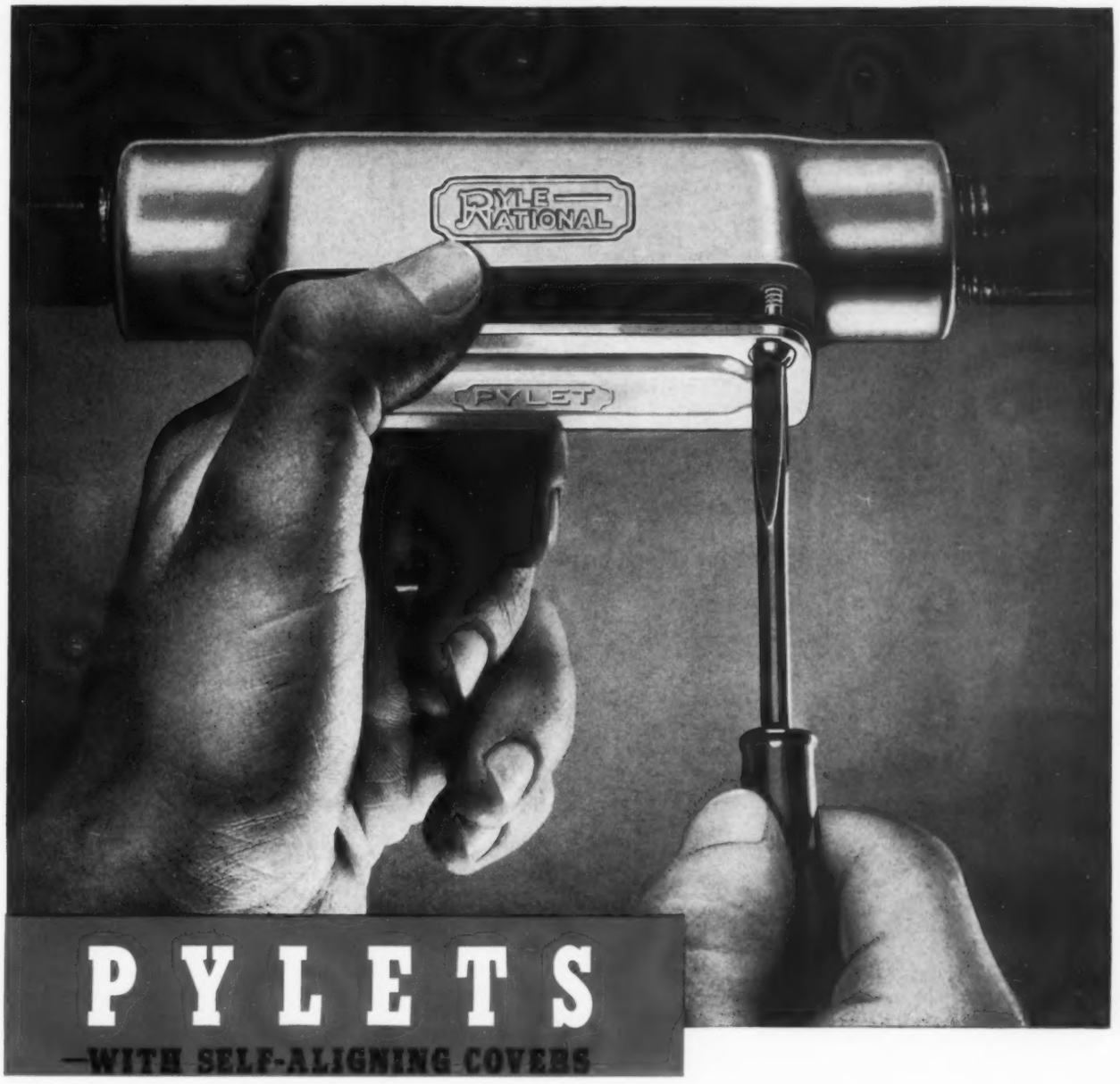

PYLETS

—WITH SELF-ALIGNING COVERS

Improved dowel-pin type Everdur screws and the counterbored screw holes in Pylet bodies make covers go on with a simple, self-positioning action that saves time and prevents trouble. Investigate the many features of this new line of conduit fittings that contribute to ease of installation, security, and economy. Write for new bulletins with complete listings of all types.

PYLE-NATIONAL

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CONDUIT FITTINGS • LOCOMOTIVE ELECTRICAL EQUIPMENT • FLOODLIGHT PROJECTORS

(*Continued from page 54*)

Iron and Steel Engineers since 1911, was recently instrumental in the formation of the Association's "Old Timers Club", which held its first meeting at the national convention in Cleveland last fall.

Lyon McCandless

was recently elected to the position of vice-president of the H. K. Porter Company. Mr. McCandless is also vice-president of the Burgess Company, Inc., located in Beaver Falls, Pennsylvania.

F. J. Dahleiden

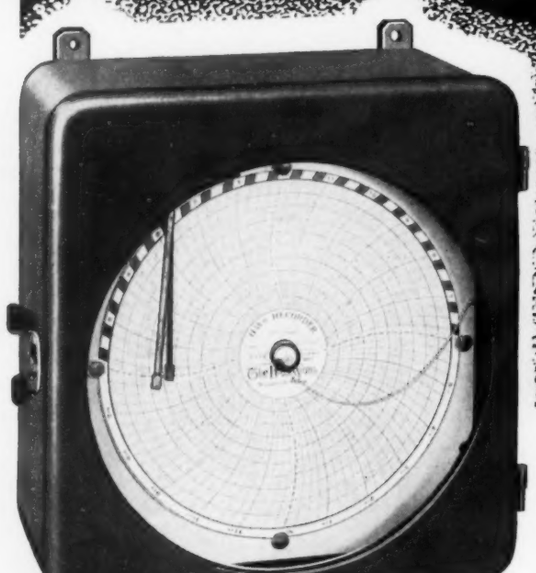
has been placed in charge of the new Ohio district office of the Okonite Company, located in the National Building in Cleveland. Mr. Dahleiden has been a sales engineer in the Chicago territory for the company.

O. P. Wilson

was recently elected president of the Norma-Hoffman Bearings Corporation, according to an announcement of the board of directors of that company. H. J. Ritter was also elected to the position of vice-president and secretary. C. B. Malone was named vice-president in charge of the plant operations.

Super-Sensitive

THE HAYS "OT" DRAFT RECORDER



For Soaking Pits, Annealing Furnaces, Open Hearth Furnaces, Slab Mills, Dry Kilns, Filters . . . wherever an accurate record of draft pressure or differential is desired

GOOD STEEL PRACTICE today demands very accurate control of furnace operation.

Here the HAYS Series "OT" Supersensitive Draft Recorders perform an invaluable service by providing that knowledge of furnace conditions so essential to control.

These HAYS instruments accurately record draft, pressure or differentials of air or gases in ranges from .1 inch water to 100 inch water (total range).

Instrument cases are of either cast iron or aluminum—to resist corrosion in different atmospheres. HAYS "OT" Recorders are built husky enough to withstand dirt-laden air and severe operating conditions yet sensitive enough to register accurately increments of .0025 of an inch water. They are built to meet your particular operating requirements. Write to 955 Eighth Avenue, Michigan City, Indiana, for more detailed information.

The HAYS CORPORATION

SINCE 1901 COMBUSTION INSTRUMENTS AND CONTROL MICHIGAN CITY, INDIANA, U.S.A

George W. Knotts

has retired from active service with the United Engineering and Foundry Company, after serving the industry for 52 years. Mr. Knotts has been associated with the Youngstown properties since they were purchased in 1917 by the United Engineering and Foundry Company from the William Tod Company. In 1893 he became mechanical engineer for National Rolling Mills, McKeesport, Pennsylvania. About 1901 he joined the Lincoln Foundry in Pittsburgh as general superintendent, and a short time later this plant became a unit of United Engineering and Foundry. Subsequently he became district manager of the Frank Kneeland plant, a part of United; in 1912, manager in charge of mechanical operations at Pittsburgh; and in 1917 he went to Youngstown. Late in the summer of 1936 he went to Ebbw Vale, England, where he supervised construction of a new plant for the Richard Thomas Company, but in December, 1937, had to return to this country because of illness in his family.

Obituaries

Harry T. Snedden

service engineer for the Electric Controller and Manufacturing Company, Cleveland, Ohio, died suddenly in his home town, Hudson, Ohio. Mr. Snedden left the Portsmouth plant of the Wheeling Steel Corporation in June 1921, to go with the Electric Controller company where he has been employed since that time. Prior to that time he had been employed by the Jones and Laughlin Steel Corporation, Carnegie-Illinois Steel Corporation, and Sharon Steel Corporation.